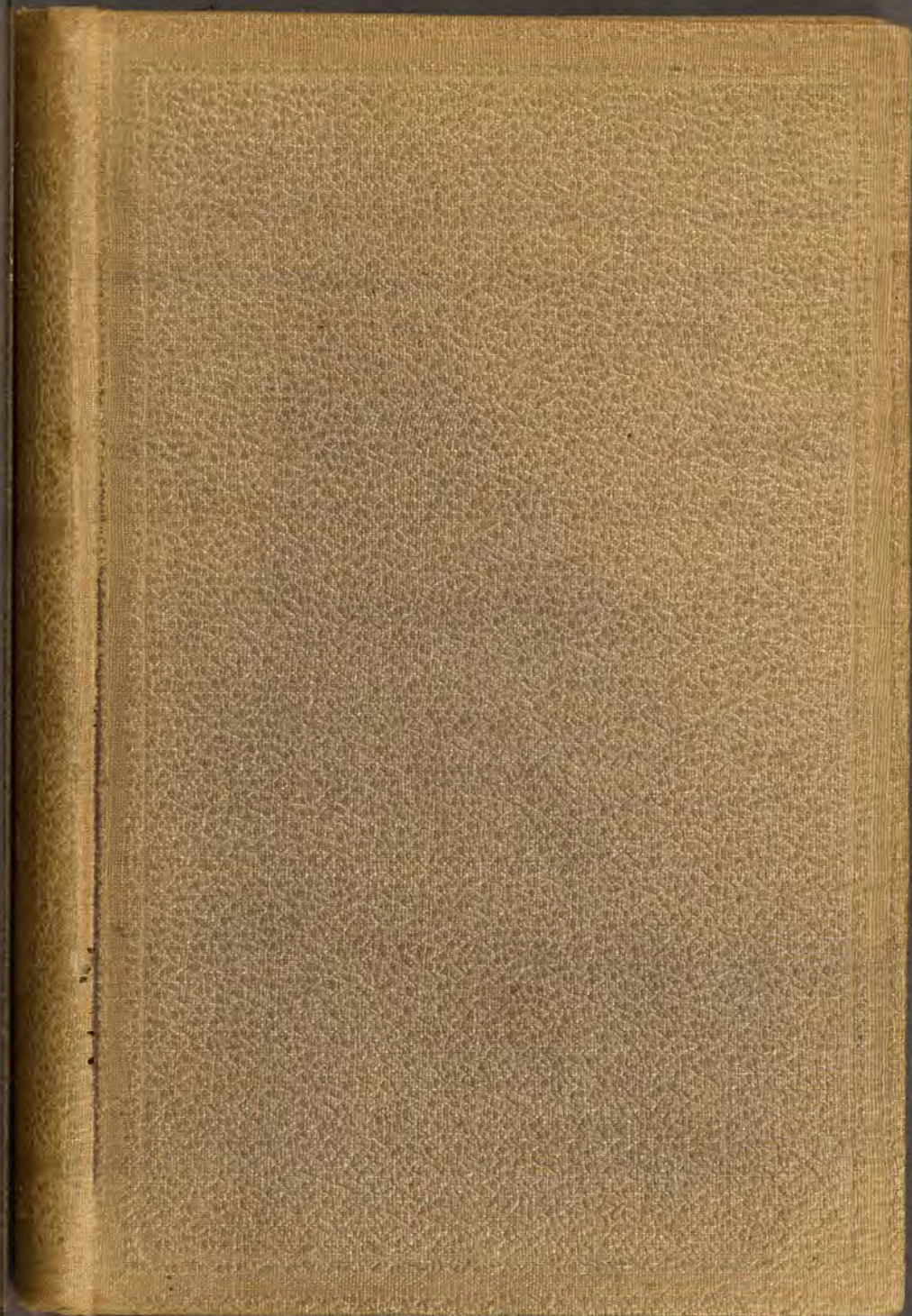
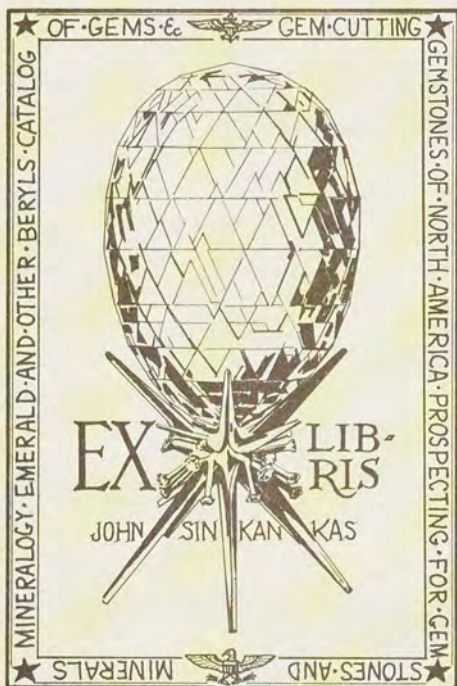
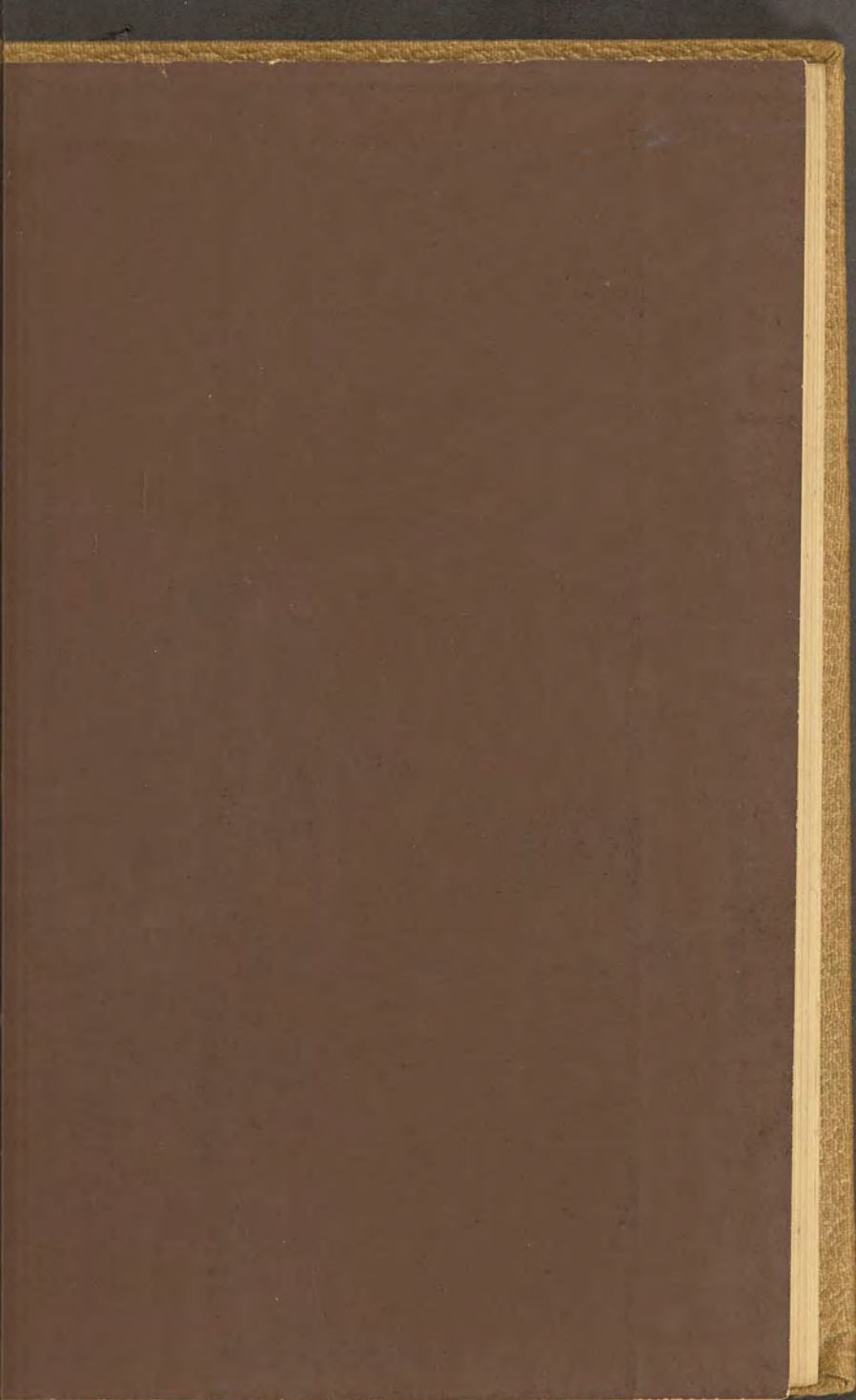
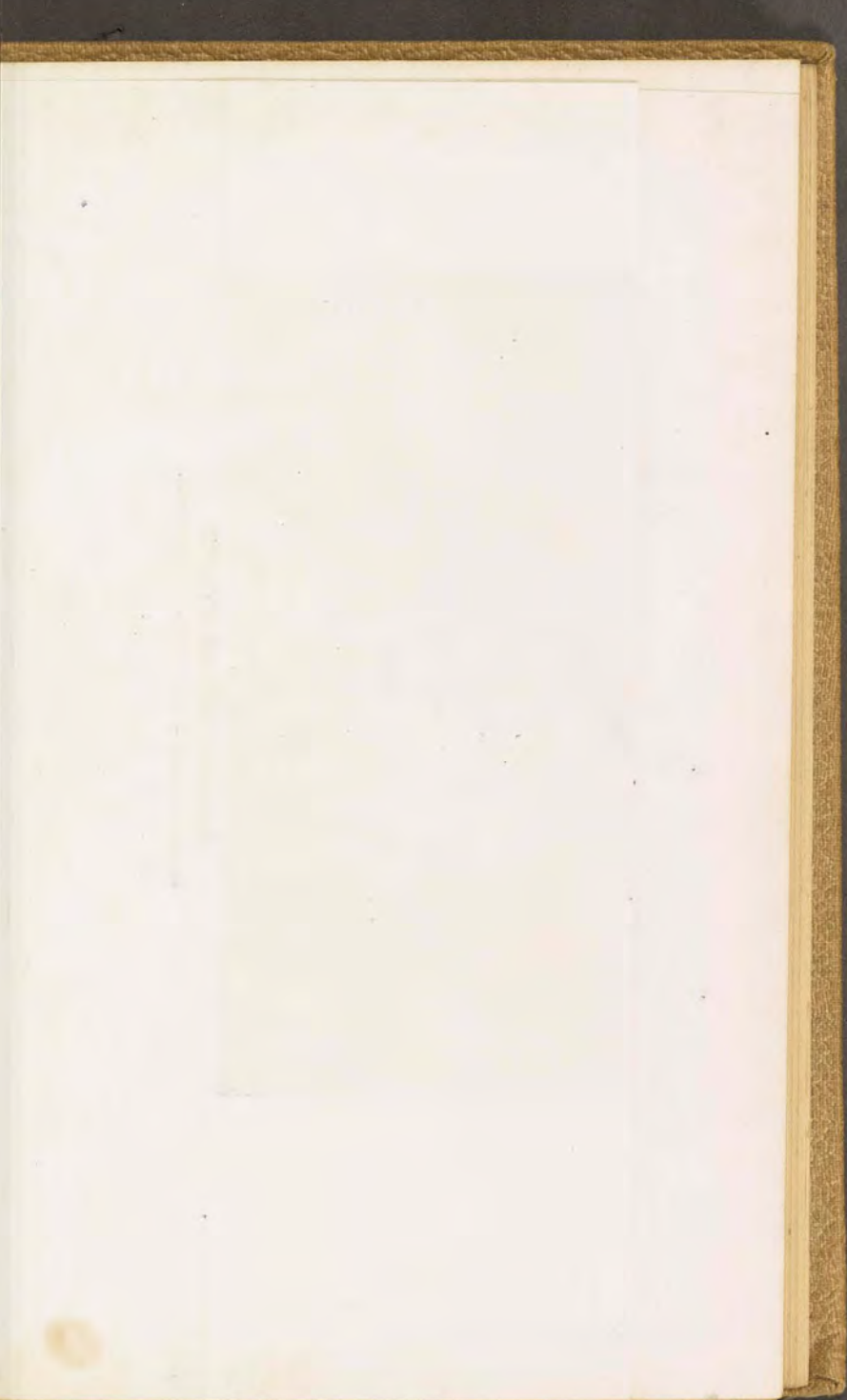








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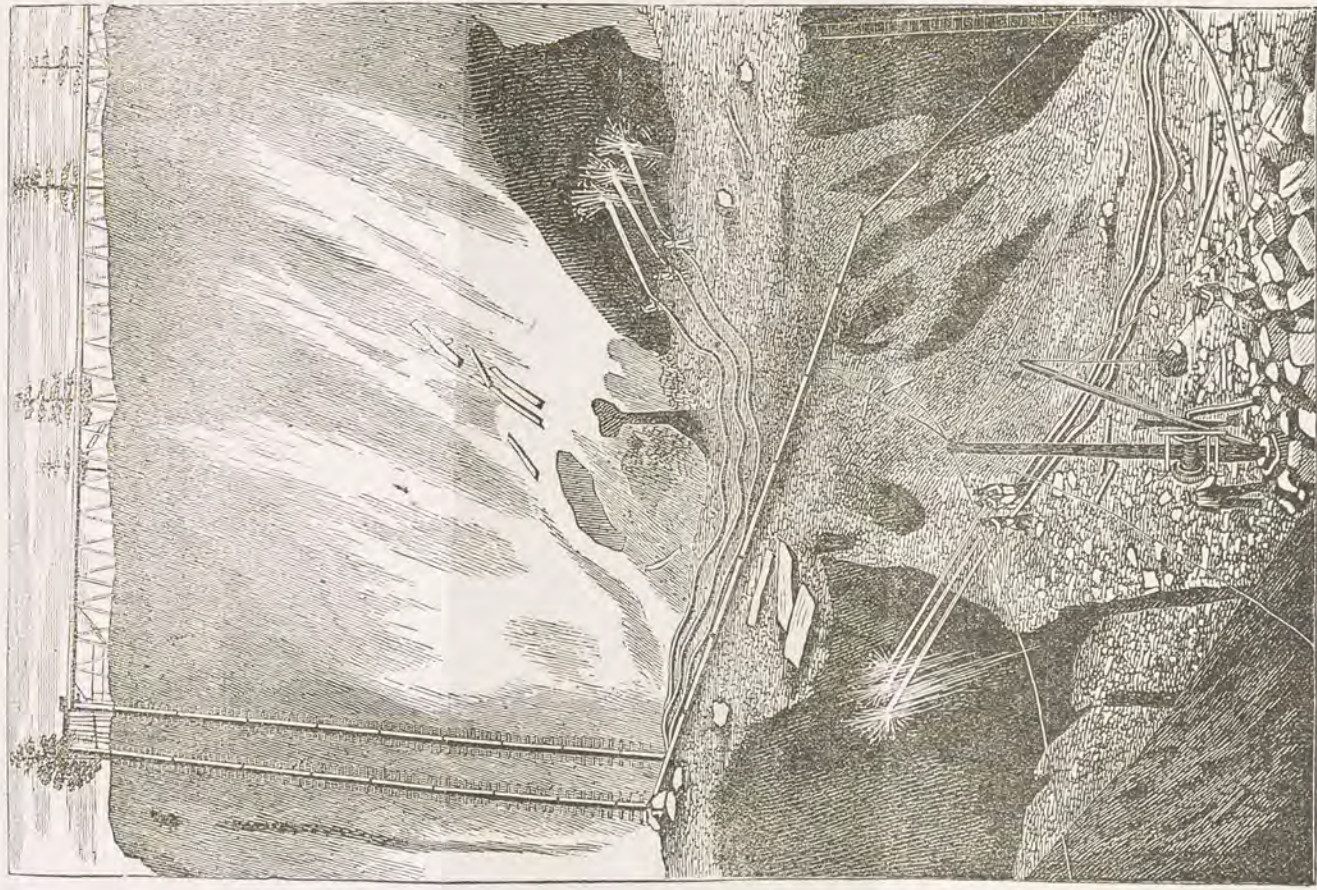


FIG. 30. HYDRAULIC MINING.
ECHEKA CLAIM, SAN JUAN, NEVADA COUNTY, CALIFORNIA.

A PRACTICAL
H A N D - B O O K

FOR

MINERS, METALLURGISTS, AND ASSAYERS,

COMPRISING THE MOST RECENT IMPROVEMENTS IN THE DISINTEGRATION,
AMALGAMATION, SMELTING, AND PARTING OF THE PRECIOUS ORES.

WITH A

Comprehensive Digest of the Mining Laws.

GREATLY AUGMENTED, REVISED, AND CORRECTED.

BY

JULIUS SILVERSMITH,

Author: "METALLIC AND AGRICULTURAL WEALTH OF THE PACIFIC STATES," ETC.

Author: "MINER'S COMPANION AND GUIDE." Editor "*American Mining Index*," New-York. Corresponding Member of the several Scientific Associations in Pacific States. Late Editor and Proprietor "*Mining and Scientific Press*," San Francisco, Cal.

FOURTH EDITION.—PROFUSELY ILLUSTRATED. ,

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1867.

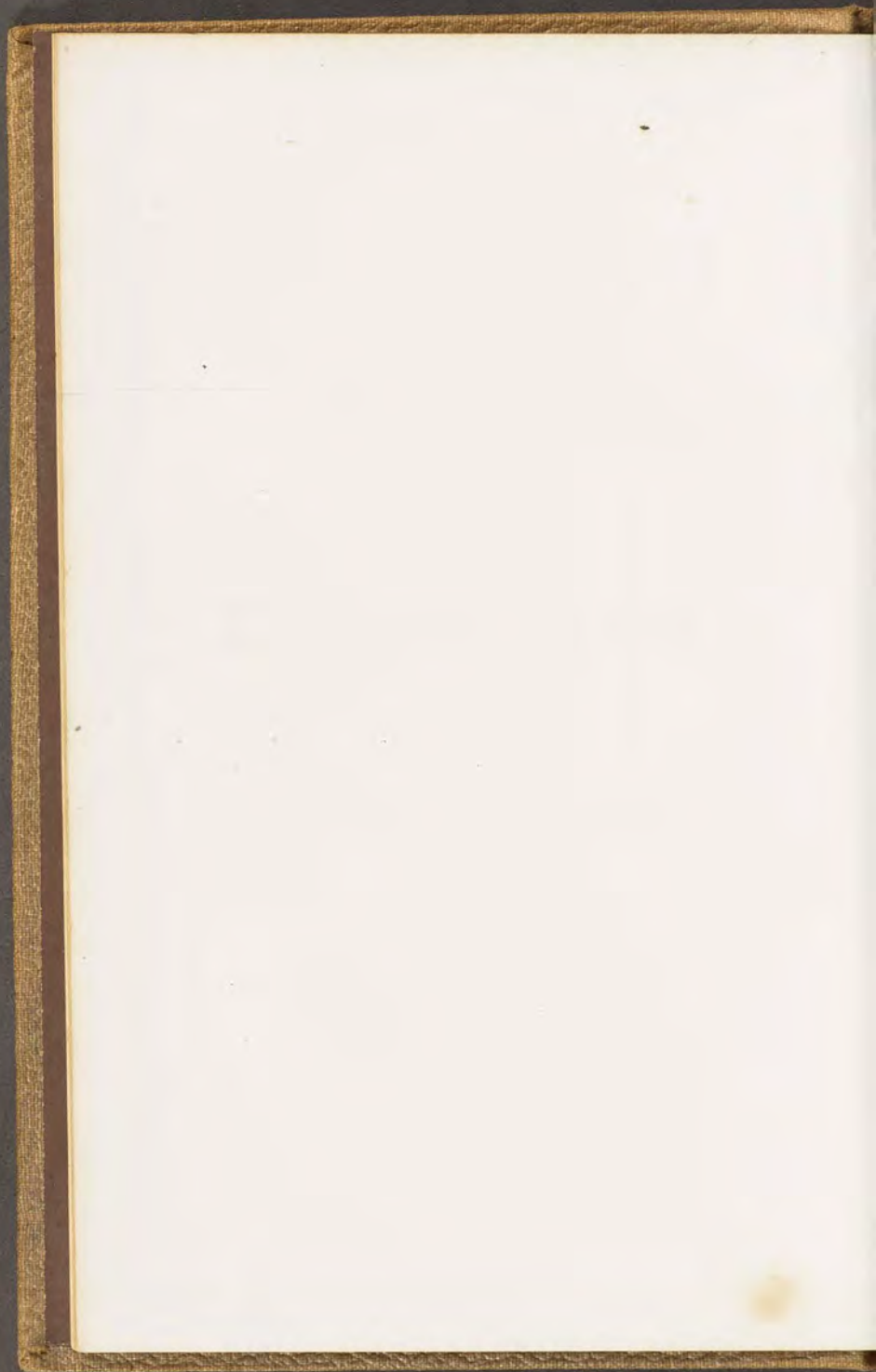
Entered, according to Act of Congress, in the year 1865, by
J. SILVERSMITH,
in the Clerk's Office of the District Court of the United States for the Southern
District of New-York.

TO

The Miners of the American Continent

THIS WORK IS

RESPECTFULLY DEDICATED.



PREFACE

TO

THE FIRST AND SECOND EDITIONS.

CALIFORNIA, since the grand exodus of the nations to her shores, commencing in 1849, has been regarded by the world almost entirely in the light of a vast gold-field. The prodigious quantities of the precious metal flowing in one continuous stream ever since that time, from her mountains and *placers*, into the lap of Europe and America and Asia, have justly earned for her the proud title of the GOLDEN STATE. But her mineral resources are by no means restricted to the noble metal—she boasts the ignoble as well. Her mines of rich cinabar have become famous. Her silver, copper, iron, and lead mines, to say nothing of her coal-fields, will yet excite the envy of other countries.

Heretofore the attention of our miners has almost entirely been absorbed in the search for gold; but a partial revulsion is taking place, and they are beginning to learn that their time may, in certain localities, be more profitably employed; and it seems like a dispensation of Providence that, at a time when our surface-diggings are yielding less profitably than of old, and many of them entirely exhausted of their riches, new and unexpected fields for mining enterprise develop themselves. Naturally enough, at such a time, the practical miner feels the necessity of having a portable mineralogical compendium, to which he can, at all times, refer when he is in doubt as to the nature of ores coming beneath his notice. Many a fortune has been within the reach of

the prospector, but eluded his grasp, simply because a handy work of reference was not in his possession. Most discoveries thus far have, in the main, been made by the merest accident, or a vague but fortunate suspicion. How invaluable, then, to those engaged in "prospecting," or actual mining, would be a convenient book in which they can find, in brief yet comprehensive shape, not only information touching the geological structure of the earth, the methods of veins, the geognostic situation, external character or appearance of the various ores, and the simplest methods of testing them; but a system of mineralogy, and the best manner of working them when found! Such a work is the "MINER'S COMPANION AND GUIDE"—which for the most part is a compilation of treatises and books whose authors rank high in the fields of geological and mineralogical research. To procure the valuable works from which we have extracted, would involve a large expenditure compared with the trifling cost of the one we herewith present to our mining community.

At considerable expense we have had wood-cuts prepared, so as to faithfully represent the subjects treated of. These illustrations and diagrams will render the most difficult portions of our volume perfectly intelligible to the general reader.

The "MINER'S COMPANION AND GUIDE" is mainly indebted to the works of Whitney, Werner, Ure, Phillips, and Orton, and we are sure that, in saying this, the miners on this coast will fully appreciate its great value. No miner or prospector, anticipating the smiles of a heretofore perverse fortune, should be without it.

PREFACE

TO

THE THIRD EDITION.

SEVERAL years have elapsed since the first edition of this work was issued, under the title of *THE MINER'S COMPANION AND GUIDE*. Since then, another edition has been called for and exhausted; and I have received so many applications for more, that a third edition is evidently needed. For these proofs of the popularity of the work I can not but feel pleased and grateful; and to show that gratitude, as well as to meet my own idea of what will do most good, I have revised the original editions, and made so many important and useful additions, as to render it almost a new work, much larger (although still of convenient pocket-size) and infinitely more valuable, not only from the amount of added material for the study and guidance of the practical miner, metallurgist and embryo assayer, but because also of the copious engravings that illustrate the same, so that even the uneducated mind will readily grasp both principles and details.

Since the first edition was issued, the field for such a work has been enlarged to such an extent that we now see Nevada, Colorado, California, Idaho, Oregon, Utah, Arizona, Washington Territory, New-Mexico, and Montana pouring forth untold treasures into the lap of the United States. Nor these alone. Since the close of the late rebellion a decided movement has taken place in the development of mines in Southern States, so that with the evident advantages of free over slave labor, we may soon expect to see Virginia and North and South-Carolina standing high in the list of prosperous mining States. Vermont and New-Hampshire, Missouri and New-Jersey,

Wisconsin and Illinois, will hereafter occupy a creditable position on the same scale, and now, within the past month, Minnesota wheels into the line of gold-bearing States. The value of such a work as this in forwarding and in a measure guiding the developments continually going on over so large a surface of the Republic can not easily be estimated. I hope and have intended that the practical miner shall find it indispensable, and, with this end in view, have employed the simplest phraseology of the vernacular.

The portion devoted to tests by blowpipe assay will be easily comprehended by all.

One of the most important features of the present edition is that in which the metallurgy of the precious metals is treated of. In it I have endeavored to embody all the processes for the reduction and manipulation of the precious ores heretofore successfully employed in Germany, England, Mexico and the United States, together with such as have been more recently invented, and not yet fully tested—all of which are profusely illustrated and easy of comprehension.

The legal profession and capitalists engaged in mining enterprises will find in it a most important Digest of State and District mining laws, rules and regulations, established in various localities throughout the country, together with Acts of Congress bearing thereon.

Having expended much time and money, with the valuable assistance of other scientific men, I have endeavored to make this *Practical Hand-book for Miners, Metallurgists, and Assayers* the greatest possible success in contributing to the development of the mineral resources of this great country. With that hope I place it in the hands of the public.

JULIUS SILVERSMITH.

PREFACE

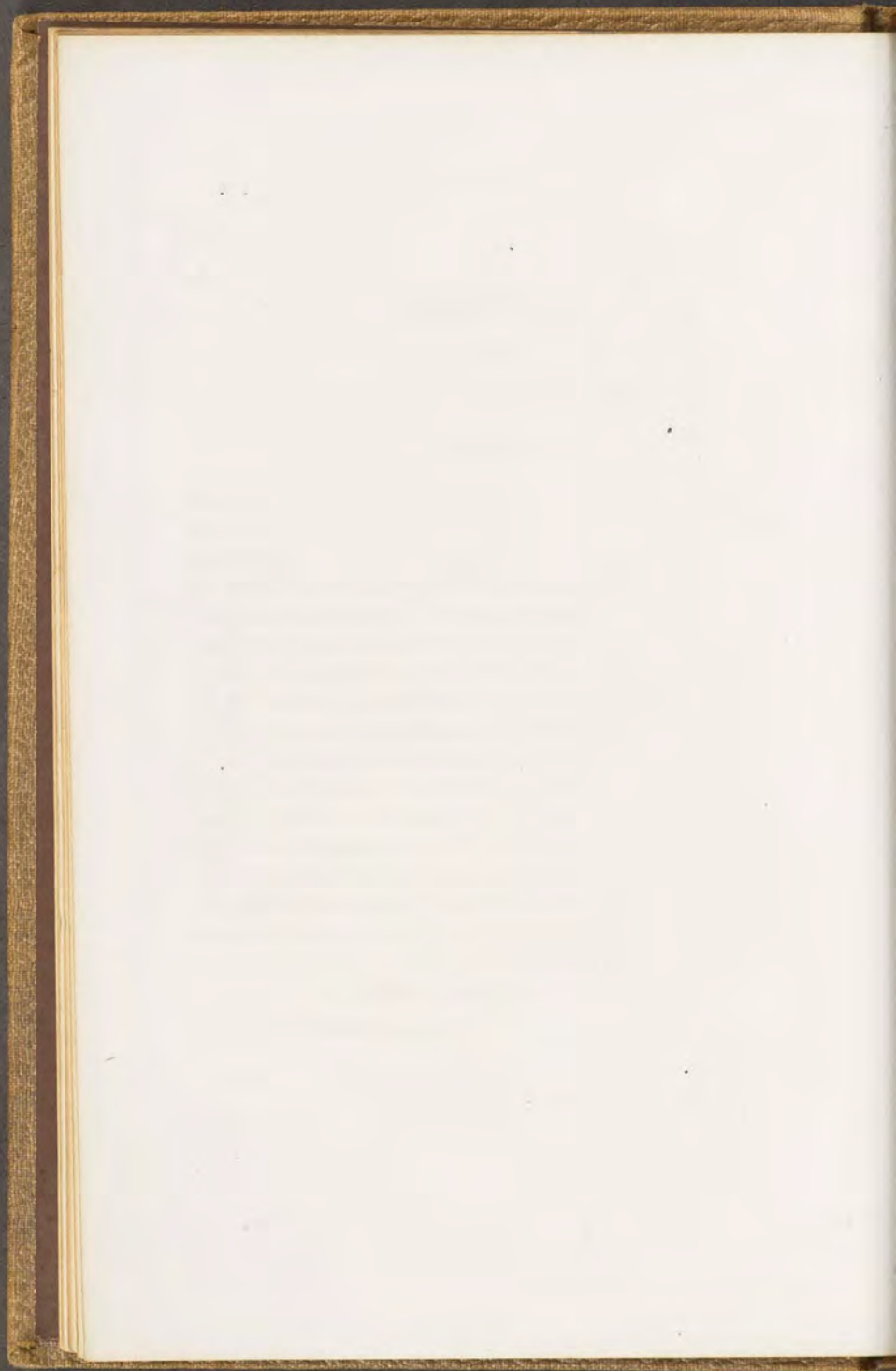
TO

THE FOURTH EDITION.

It is but a short while since the third edition of this work passed through the press, and the demand for the work has been greater than anticipated. Having thus been encouraged by a discerning public who seem to appreciate my humble endeavors, I have again largely augmented, revised, and corrected the stereotype plates, especially so with reference to the addition of the Congressional Mining Laws as passed during the month of July, 1866. The last edition went to press rather hurriedly, hence many typographical errors appeared throughout the text; these have been corrected so far as human eyes could detect. Cognizant that I have contributed to the miner, pioneer, and explorer a handbook containing a vast amount of information obtained only through years of experience, I trust they will be benefited by the plain and practical principles in the several departments pertaining to mining, metallurgy, etc.

Very respectfully,

JULIUS SILVERSMITH.



THE MINER'S HAND-BOOK.



PRINCIPLES OF MINING.

On the Nature of the Deposits of the Metals and their Ores, and the General Principles on which Mining is Conducted.

BEFORE entering upon a description of the mode of occurrence and geological position of the various metals and their ores, taken singly, it will be well to establish the meaning of some of the more important terms used in treating of subjects of this kind, and to lay down some general principles which the results of mining experience have shown to be applicable to mineral and metallic deposits. The importance of this preliminary step will be acknowledged when it is considered that these principles are derived from the combination and classification of facts observed in mining operations all over the world, and that they form the basis on which future enterprises of this kind should be organized. The results which have been obtained in this branch of applied science are drawn from a great variety of sources; and when we reflect on the expense and well-known uncertainty attendant on mining, it will be evident that, amid the multitude of isolated facts, to which every day is adding, some general principles should be recognized which may be relied on as a thread to guide one through the labyrinth of uncertainty.

Great as is the variety of forms under which the metalliferous deposits of different regions appear, and difficult as it may seem at first sight, to discern any fixed laws in their development, yet a general consideration of their structure will justify the following classification.

I. SUPERFICIAL.

II. STRATIFIED.

III. UNSTRATIFIED.

- | | | |
|-------------|---|--|
| | { | <i>a.</i> Constituting the mass of a bed, or stratified deposit. |
| | | <i>b.</i> Disseminating through sedimentary beds. |
| | | <i>c.</i> Originally deposited from aqueous solution, but since metamorphosed. |
| | { | <i>a.</i> Masses of eruptive origin. |
| | | <i>b.</i> Disseminated in eruptive rocks. |
| | | <i>c.</i> Stockwerk deposits. |
| | | <i>d.</i> Contact deposits. |
| | | <i>e.</i> Fahlbands. |
| | { | <i>f.</i> Segregated veins. |
| | | <i>g.</i> Gash veins. |
| | | <i>h.</i> True or fissure veins. |
| A. Regular. | | B. Irregular. |

I. SUPERFICIAL DEPOSITS.—These comprise all deposits of the metals and their ores, which lie loose upon the surface, or intermingled with the superficial formations, the drift, and the alluvial. They are made up of particles and rounded fragments which have originally formed a part of some bed or vein, and from which they have been detached by various causes similar to those which have produced the great masses of clay, sand, and gravel, which almost everywhere cover the rocks in place. Such metalliferous deposits are usually called washings, or stream-works. Most of the gold and all of the platina of commerce is obtained in this way, as also some of the tin. Their discovery and exploitation is hardly to be classed under the head of mining operations, although they furnish large amounts of the most valuable metals. Lying so near the surface, they can be reached by excavations of the most simple character. The dissemination of the metallic substances through the loose materials in which they are imbedded is the result of mechanical causes, especially of currents of water, which have torn them from their original bed, and scattered them over the surface.

II. STRATIFIED MINERAL DEPOSITS.—This class of deposits comprehends those masses of ore which are included within rocks of sedimentary origin, and which are in every way identical in their epoch and mode of formation with the strata between which they are accumulated. This is not, however, the mode of occurrence of the more valuable metals. Of all the metalliferous ores, those of iron and manganese only occur in stratified deposits on an extensive scale. The beds of argillaceous ironstone, intercalated among the shales of the coal series, furnish the most striking illustration of this mode of occurrence, as will be fully set forth elsewhere.

There are also strata of slaty and other rocks which are impregnated with ore, or contain it disseminated through them in small particles, so thoroughly intermingled with the rocks as to be hardly distinguishable from it. When such deposits occur on an extensive scale, and when the ore forms a persistent portion of the stratum, they become an important source of mineral wealth; although the percentage of ore is usually very small, yet from their great extent, they may be capable of being worked with profit. Such are the cupriferous schists and sandstone of the Mansfield district in Prussia, and the similar deposits of the government of Perm in Russia.

There is a class of metalliferous deposits which belong to rocks originally stratified, and of aqueous origin, but which have, since their deposition, been metamorphosed so as to have assumed in a great degree the appearance of igneous masses, and which themselves can with difficulty be recognized as possessing distinctly the character of either the stratified or unstratified groups. These are developed in the metamorphic strata of the palæozoic system, but especially in the azoic rocks, as in Sweden and in Northern New-York, where the immense deposits of iron ore furnish examples of the class in question. They invariably coincide in their line of greatest linear development with the line of strike of the associated rocks, and are exceedingly irregular in

their dimensions, expanding to a great width, and then contracting within very narrow limits. They usually also agree in dip with the planes of the rock inclosing them. Such masses of ore seem to have resulted originally from aqueous deposition, although the materials may in some instances have been derived from the abrasion and destruction of purely igneous masses. It is frequently supposed that these lenticular, or flattened cylinder-shaped deposits have been forced up in a plastic state from beneath, having been driven in between the strata like a wedge, separating them along the line of least resistance. This theory, however, seems hardly tenable, when we consider the great extent of such masses, and the absence of rubbed and polished surfaces along the line of contact of the ore and of the adjacent rock. Moreover, such masses are sometimes found thinning out beneath, as if they had occupied a previously existing depression in the strata, before they had been elevated from their original horizontal position. When such an upheaval of metallic matter has taken place from beneath, we find the result of mechanical displacement and chemical action in the surrounding beds to be most strongly marked. The azoic period having been one of long-continued and violent mechanical action, there is no reason to doubt that many of the masses of which it is made up may have been derived from the ruins of previously formed rocks of the same age, both sedimentary and igneous. Such abraded material might readily have been swept into the depressions of the surface by strong currents, such as must have existed in those times, and would naturally have a very irregular thickness.

III. UNSTRATIFIED DEPOSITS. — This class comprehends most of the deposits of the ores of the metals, excepting some of those of iron and manganese, as noticed above. Their character is exceedingly varied, and the phenomena which they exhibit, frequently of the most complex kind.

In the first place, they may be divided into two great groups, *Irregular and Regular Deposits*.

Irregular Deposits.—These include, first, igneous eruptive masses, forming rock aggregations in every respect similar in form and mode of occurrence to the non-metalliferous rocks with which they are associated. This class of deposits consists chiefly of the immense masses of specular and magnetic oxyds of iron, so strikingly developed in the azoic system, where they exist in connection with igneous eruptive rocks, and apparently under the same conditions and with the same mode of occurrence. In Europe, the Elba iron ores may be taken as a type of this class of ore deposits; in this country, the Iron Mountain of Missouri, and the even more extensive iron ridges of Lake Superior, furnish striking examples of a metalliferous ore existing in such quantity and under such circumstances as to identify it geologically with the adjacent rock formations, and to cause it to be classed with them, as having originated under the same circumstances. Such bodies of ore usually form ridges parallel with the lines of elevation of the rocky strata in which they occur, or they may take the form of dome-shaped masses, which have lifted up the strata on every side, usually filling the fractured envelope with metallic emanations, and showing an intense metamorphic action in the formation of numerous mineral substances not elsewhere found occurring in the formation. As might reasonably be expected, such ore-masses are often developed on the largest scale in the azoic system, having been formed at a period in the geological history of the earth when its crust was thinnest and most easily fractured. If there have been eruptions of metalliferous masses during the later geological periods, they have taken place usually in a region of volcanic fires, or on deeply seated fissures which have remained opened until a late epoch.

As far as the practical application of mining science to this class of deposits is concerned, it is the most simple, for they are developed on so grand a scale that there is no question of exhausting them, and when worked, it is generally by excavations of the nature of the quarry rather than of the mine. In that part of

Whitney's *Metallic Wealth*, treating of the geological occurrences of ores of iron, numerous examples are given of this form of metalliferous deposit, which is almost exclusively confined to that class of metalliferous products.

Closely allied to the last-mentioned class is that of the metals and ores disseminated in the eruptive rocks, when the quantity of the metalliferous substance has not been sufficient to form a special deposit, or when the nature of the circumstances under which it was formed has not permitted its concentration. This is the mode of occurrence of platina and its associated metals, which are disseminated through eruptive trappean or serpentine rocks in fine particles, and rarely masses of a few pounds in weight; but which have never, thus far, been found in regular veins or in any concentrated form of deposit. Serpentine is frequently accompanied by chromic iron, which is disseminated through it in the same way, but much more abundantly. The trappean rocks contain frequently so large a proportion of the magnetic oxyd of iron, scattered through the mass, that it may be considered one of the constituent minerals of the rock. Thus, in the mine of Taberg, in Sweden, the trap is so filled with bunches and strings of magnetic iron ore that it can be worked to advantage.

But in general, this class of deposits are of little value, unless nature has performed the operation of separating the metallic contents on a grand scale, by a gradual disintegration and removal of the rocky substance, and the consequent concentration of the much heavier metal or ore. This is the origin of all the platina-washings, which metal was derived from the abrasion of a rock containing it in so small a proportion that it could never have been separated by artificial means, with profit.

The tin mines of Europe are, many of them, worked in deposits analogous in their mode of occurrence to those now under consideration. For instance at Geyer in Saxony, the oxyd of tin is found in small thread-like veins, and disseminated in fine particles through an erup-

tive dome-shaped mass of granite. It is from an original source resembling this, that the tin of the washings or stream-works of England and the East-Indies has been in part derived. Oxyd of tin is sometimes disseminated in invisible particles through the granite rocks, and would probably be frequently found if carefully searched for. Professor Whitney found 0.13 per cent of this substance in a feldspar from the Riesengebirge, in Silesia, in which not a particle of it was visible to the eye.

Closely allied and passing into the last-mentioned mode of occurrence is that called by the Germans a "Stockwerk," a term which has been adopted into French and English, although not always correctly applied. The stockwerk consists of a series of small veins, interlacing with each other and ramifying through a certain portion of the rock. The ore is not usually entirely confined to the veins or branches, but exists in the adjacent rock in considerable quantity.

The annexed section (Fig. 1) represents such a network of veins, and the manner in which they may be imagined to traverse the rock.

Such reticulations of mineral matter are frequently called in England, "floors," and in Germany, "trümerstocke," or "stockwerke," in allusion to the fact that they are worked in different stages or stories, one above the other, owing to their great extent. Such deposits are

Fig. 1.



usually proportionally poor in metallic content, in an average of the whole quantity of rock which has to be worked.

The celebrated Carclase tin mine, near St. Austell, is a striking example of the stockwerk form of deposit. It was worked until recently, in a decomposed feldspathic

granite, as an open quarry. The ore occurs in a network of small veins interlacing with each other, the whole of which, together with the rock included between them, had to be removed, and the ore afterward separated by hand-picking, stamping, and washing.

There are other stockwerk mines in Cornwall, most of which have now been worked out and abandoned. The Altenberg stockwerk, in Saxony, furnishes another good example of this mode of occurrence. The rock is a grayish silicious, feldspathic porphyry. The stanniferous mass is about fourteen hundred feet long, and nine hundred feet wide, and, like that described above, consists of a number of small veins, which cross each other in every direction. Those which run nearly east and west are usually the widest and richest in ore. The inclosing rock is also rich enough to be stamped and washed for a distance of several feet from the network of veins.

In the phenomena of contact deposits, segregated veins, and true veins, there is a gradual passage from one class of forms to the other, so that it is not always easy to say to which of these divisions a deposit of ore may belong. In the class of contact deposits, the ore is found concentrated between two formations of dissimilar geological and mineralogical character. Where the strata have been uplifted and metamorphosed by a central eruptive mass, not unfrequently a band of metalliferous ore, of irregular thickness, will be found extending along the line of contact of the eruptive with the metamorphosed rock. Or, if not always exactly upon the dividing line between the two formations, it may be found perhaps at an inconsiderable distance, and preserving a general parallelism with it. The annexed figure (2) illustrates, by an ideal section, this mode of occurrence.

In the same manner, beds of ore may be found between two successive overflows of an igneous



a. Contact deposit of ore bet. 2 formations.

rock, or metallic substances may occur disseminated through that portion of two beds of rock which is adjacent to the plane of separation between them; in such a case the mineral masses on each side of the ore deposit may have the same geological position, but will usually be found to differ in mineralogical character. Farther on, interesting examples of this mode of occurrence, in the Lake Superior region, will be given. The iron ores of the Harz have a similar position in relation to the eruptive rocks of that district, since they follow the contact-planes of these igneous masses with the uplifted slates. The deposits of ore pass gradually into the trappean rock, showing that there has been a concentration of metallic matter at the junction of two dissimilar formations. The same phenomena exhibit themselves in the Vosges, near Framont, where masses of specular iron surround a central nucleus of quartzose porphyry, which has tilted up the stratified rocks, while the ore has insinuated itself into all the fractures and cavities thus produced, lining them with beautiful crystals, and penetrating even into the solid rock itself. At this locality, and others resembling it, the action may be considered to have been principally of an igneous character, the upheaval of the strata opening a passage or chimney for the passage of metallic vapors which have become condensed in the fissures thus formed. In other cases the phenomena are more satisfactorily explained, by supposing a segregation of the mineral substance along the line of junction of two rocks of dissimilar character, under the influence of electro-chemical agencies. The copper ores of Monte Catini, in Tuscany, belong, according to Burat, to the class of contact deposits, being developed along the line of outcrop of the gabbro, a rock resulting from the metamorphic action of serpentine upon the strata of the cretaceous formation.

Deposits of the character thus indicated are exceedingly irregular in their outline, and are often so combined with each other as to present the features of two or three forms at once; but in general, in their essential characteristics, they are allied to the rocks in which they

occur, in structure and composition. They are often developed at certain points on so large a scale as to be of great importance, but they have not that persistence in depth which is the characteristic of true veins. The ores which they furnish are less crystalline in their texture, and are often quite compact. The gangues are also less distinguishable from the adjoining rocks, and frequently there is no proper veinstone at all. In every mining district, one or the other of these modes of occurrence usually predominates and gives a character to the workings; if the deposits are of the irregular class, they are usually wrought with less skill and capital, although frequently on a very extensive scale; if, on the other hand, they are regular in their character, they require an enlightened system of working, and may be relied on as permanent sources of metallic wealth. Of this description are the mines of Cornwall, Saxony, and the Harz, which have been for hundreds of years the classic regions of mining, and in which the theory and practice of this branch of applied geology have been carried to the highest perfection.

Intermediate between the regular and irregular deposits of the metalliferous ores are those forms of occurrence designated by the German word, "fahlband." These are more strikingly exhibited in Norway than elsewhere, although the same character has been recognized in other regions on a less extensive scale; and being in some respects peculiar, this mode of occurrence should not be overlooked in a review of the forms of metalliferous deposits.

The fahlbands, (German fahlband; plural, fahlbänder,) as developed in the district of Kongsberg silver mines, consist of parallel belts of rock of very considerable length and breadth, which are impregnated with the sulphurets of iron, copper, and zinc, together with a little lead and silver, disseminated through the rocks in such fine particles as to be hardly visible, and only to be recognized by their tendency to decompose, and thus to give the rock in which they are contained a peculiar rotten and disintegrated appearance at the surface; hence

the name fahlband, or rotten belt, the word *fahl* being a corruption of *faul*, the miner's term for a rotten or decomposed rock.

In general, these ore-bearing belts are irregular in their dimensions, although constantly observing a certain degree of parallelism with each other. They may be traced in the Kongsberg silver-mining district for several miles, and the greatest depth of any one is about a thousand feet. The quantity of ore contained in them is usually too small to be worth working: but occasionally it is sufficiently concentrated to become the object of mining enterprise. There are seven of these fahlbands in the vicinity of Kongsberg, and they are parallel in strike and inclination with the gneissoid and schistose strata in which they occur, and have the same local character in relation to disturbances of stratification, schistose structure, and other external forms.

The fahlbands, however, are themselves traversed by fissure-veins bearing argentiferous ores, and the results of extensive mining have shown that these veins are only productive when they intersect the fahlbands, demonstrating that the impregnation of the lode with mineral matter was entirely dependent on the nature of the adjacent rock, and furnishing sufficient evidence that the metalliferous particles in the veins were originally derived from the fahlbands, and probably concentrated there by electro-chemical action.

This mode of occurrence will be recognized as peculiar in its character, being a combination of two distinct forms of metalliferous deposits; but the fahlbands themselves could hardly be considered of much importance, were it not for their enriching action on the lodes which traverse them.

The same fact is observed with regard to the enriching of fissure-veins, when they traverse different beds of rock, even in cases where no perceptible metalliferous particles can be observed in any of them, and when the fahlband structure may be supposed to be wholly absent. In such cases it is not unreasonable to suppose that a chemical examination of these beds, in which a lode

shows itself to be better filled with ore than elsewhere, might reveal the existence of metalliferous particles, the presence of which had been previously unsuspected, because they were too finely disseminated through the rock, or were not of a nature to be easily decomposed, and so failed to give a marked external to the stratum in which they occurred. The fahlbands may be considered as approaching nearest to the class of segregated veins, which comes next in the classification of metalliferous deposits given above, and to these, in connection with the other modes of occurrence to which the term Vein is applied, we now turn our attention.

Regular Deposits.—Segregated Veins, Gash-Veins, Fissure-Veins.—The line of demarkation between the three forms of veins indicated above, can not always be easily drawn, although in most cases the difference is very apparent, and in all is of great importance in judging of the value of a metalliferous deposit. But in some instances, there is so gradual a passage from one form to the other, that surface examinations are not sufficient to enable one to decide the question of the actual existence of a fissure or true vein, and it is only by the indication obtained at some depth below the surface, that the vein can be placed in its proper class.

By a vein, as a geological and mining term, in general is understood *an aggregation of mineral matter of indefinite length and breadth, and comparatively small thickness, differing in character from, and posterior in formation to, the rocks which inclose it.*

Werner, the great Saxon geologist, defined veins as "mineral repositories of a flat or tabular shape, which traverse the strata without regard to stratification, having the appearance of rents or fissures formed in the rocks, and afterward filled up with mineral matter differing more or less from the rocks themselves." This definition would exclude many veins which do not traverse, but run parallel with the strata, and others which occur in unstratified rocks. The definition given above, of course, includes veins of mineral matter not metallifer-

which are of frequent occurrence, but, of course, no importance in the present connection.

Weissenbach, in a paper published in Cotta's "Contributions to the Knowledge of Mineral Veins," which is especially devoted to the subject of the metalliferous lodes of Saxony, has given a general classification of all the modes of occurrence which can be brought under the head of veins. He divides them as follows:

1. *Veins of Sedimentary Origin*.—Where a fissure has been filled from above by deposition of mineral matter, in a manner similar to that in which the sedimentary rocks themselves have been formed. The origin of these is exceedingly simple, since it is evident that in the process of deposition of any of the stratified masses, as of sandstone or limestone for instance, if this operation were going on in a region where open fissures existed in the subjacent rock, they would be filled by the sedimentary matter, which would assume a stratified appearance in the fissure exactly as above it. The matter thus deposited would not properly be a metalliferous ore, since this class of products have a chemical not a mechanical origin. This is perfectly evident, and it can not fail to strike one with surprise that a theory so inconsistent with facts should have been adopted by Werner to account for the formation of metalliferous veins. The whole class of veins of sedimentary origin is of little importance.

2. *Veins of Attrition*.—Fissures filled with matter introduced by purely mechanical means, such as by fragments of the wall-rock falling from above, or produced by friction of their sides against each other. These phenomena are exhibited in many ore-bearing veins, in the formation of which a two-fold action was concerned.

3. *Veins of Infiltration, or Stalactitic Veins*.—These result from the filling of fissures by incrustation of the sides with calcareous matter deposited from aqueous solution, in the manner of the stalactites so common in caverns.

4. *Plutonic Veins*.—Fissures filled with mineral matter identical with that of rock formations, or mountain masses, and supposed to have been introduced by injection, or pressure from beneath upward, while in a plastic state. Such are the common granite veins in granite or slate.

5. *Segregated Veins*.

6. *Metalliferous Veins, proper*.

These two latter classes are included in the class of regular, unstratified mineral deposits, as previously shown in the table of mineral formations; the latter division including both gash and fissure veins; and they are the only ones which are of importance in the consideration of the metalliferous veins.

Segregated Veins.—Under this class of metalliferous deposits are included those vein-like masses which have a crystalline structure, or, at least, a gangue differing from the adjacent mass, but which do not seem to occupy a previously existing fissure in the rock, being so enveloped and limited on all sides within it, as to show that the metalliferous and mineral substances of which they are made up could not have been introduced into their present position in any other way than by a gradual elimination of their component particles from the surrounding formation. This process seems to have been of a chemical nature, and one by which materials of similar character were collected together from all directions, or segregated, as it is termed. Of the conditions under which the adjacent rocks must have been when such an elimination of their metallic contents took place, we know little with certainty. We see, however, examples of segregation in masses of lava, as they cool from a state of igneous fluidity, when crystals of the different mineral species found in such rocks are found to have crystallized out into distinct individuals, from what was before an apparently homogeneous paste. The same is true of granite and the trappean rocks. In the former, the single crystals sometimes attain the length of several feet. If circumstances cause the segregating crystals to imitate an elongated mass, we have at once the rudi-

mentary form of a vein-like mass, which may continue to develop itself and acquire considerable dimensions. A tendency to this separation of pure quartzose material will be noticed in almost all of the so-called metamorphic rocks, which frequently show bands of pure quartz, parallel with each other, and lying in the plane of stratification of the inclosing rock; and it should be noticed that quartz is almost universally the veinstone of ores occurring in this form of deposit.

These segregated veins differ from true veins in some important respects.

Fig. 3.



a. Segregated mass of ore cropping out at the surface.

b. Parallel layer not extending upward so far.

deposit here under consideration. The ore-bearing mass may or may not appear at the surface, but its extent downward in one plane is not to be relied upon as in the case of a fissure vein, since the accumulation is

Fig. 4.



Section of the Rammelsberg.

liable, at any point, to be found thinning out in depth, and transferred to another plane, as represented in the figure.

A striking illustration of this form of deposit may be seen in the Rammelsberg, one of the most celebrated localities of the Harz, a section of which is given in the annexed cut, (Fig.

4.) The principal mass of ore (*a, c*) lies in the direction of the argillaceous slates of which the mountain is made up. At the depth of about four hundred feet it sends off a branch, (*b*), which dips at a considerably less angle than the slates themselves. The greatest thickness of the mass of ore is over one hundred and fifty feet; and its length is about nineteen hundred; but the dimensions decrease in depth, and at eight hundred feet its thickness is about twenty, and its length seven hundred and fifty feet; so that there can be little doubt that the mass will terminate entirely at a certain not very great depth. The ores of this singular mass are chiefly sulphurets of iron, zinc, lead, and copper, intimately blended together, and almost entirely destitute of gangue.

The auriferous quartz-veins of most gold regions belong to this class of deposits. They consist of belts of quartzose matter with sulphuret of iron, which near the surface is decomposed into a hydrated oxyd, and contain gold disseminated through these substances, and sometimes in the adjoining rock, in fine particles, or, occasionally, large lumps. These belts run with the strata and dip with them, and in other respects exhibit the phenomena of segregated rather than of fissure veins.

Practically, the most important feature of this class of deposits is, that they can not be depended on in depth as true veins, as they seem almost always to be richest near the surface, and frequently terminate altogether at no very considerable depth. Nor is the ore or metallic matter distributed through them with as much regularity as in the true veins, forming often a series of nests and pockets ranged in a general linear direction, and connected by mere threads of ore or barren vein-stone.

Gash-Veins.—This variety of mineral deposit holds an intermediate place between segregated and true veins. Like the latter, they occupy preëxisting fissures; but these are of limited extent, and not connected with any extensive movement of the rocky masses. They are

usually confined to a single member of the formation in which they occur, terminating below, when a marked change in the lithological or mineralogical character of the rock takes place. The annexed cut (Fig. 5) represents, in an ideal section, the mode of occurrence to which the name of gash-veins is applied. The stratum *b*, included between *a* and *c*, cuts off the veins in *a* entirely, the fissures not having extended through that bed at all. Should circumstances favor, and the bed *c* resemble *a*, similar

Fig. 5.



Gash-Veins.

the mode of occurrence to which the name of gash-veins is applied. The stratum *b*, included between *a* and *c*, cuts off the veins in *a* entirely, the fissures not having extended through that bed at all. Should circumstances favor, and the bed *c* resemble *a*, similar

fissures may be found again below *b*, as presented in the figure, but it can by no means be asserted that they are the continuations of the identical fissures which were found in *a*; on the contrary, they are a new set, originating in and comprised in the bed *c*, as those above were in *a*. Lateral branches will usually be found in connection with the main fissures, which may or may not be nearly vertical, according to circumstances; but, whatever their position, the two sets of cracks will be nearly at right-angles with each other, and will possess the same character in regard to their mineral contents, although one set will generally predominate over the other greatly in extent.

The origin of this class of fissures must, in all probability, be referred to the contraction of the rock caused by shrinkage, either while gradually undergoing consolidation, or from the effect of long exposure to a somewhat elevated temperature, after a cessation of which, certain strata might, on cooling, under peculiar circumstances of texture and thickness, be more liable to be fissured than others.

The filling of fissures thus originating with mineral substances, may have taken place in various ways. Most of them in process of deposition, if they occurred in strata still accumulating. In a rock impregnated with

metalliferous combinations, segregation would more readily take place from the walls of such cavities, and their contents would then have the characters of those of segregated veins. From true fissure veins they differ especially in not showing as distinctly marked selvages, and in having a less crystalline and comby structure of the veinstone. They are especially to be found in the unmetamorphosed sedimentary rocks, where these have undergone so little change as not to have assumed a thoroughly crystalline texture, and have retained the original lines of stratification, which, in the fully altered rocks, are almost obliterated.

The difference between segregated and gash-veins may be sometimes hardly perceptible, but their origin is sufficiently distinct to justify their separation from each other; and there are mining regions where the peculiarities of one form or the other may be seen with great distinctness. The latter are still less reliable than the former, and are usually soon worked out in depth; but frequently their number makes up for a want of continuous extent in any one of them, so that a region where they abound may furnish, for a time, a large amount of ore.

True Veins.—A true vein may be defined as a fissure in the solid crust of the earth, of indefinite length or depth, which has been filled more or less perfectly with mineral substances; or, in other words, an aggregation of mineral matter, accompanied by metalliferous ores, within a crevice or fissure which had its origin in some deep-seated cause, and may be presumed to extend for an indefinite distance downward.

These veins are almost universally admitted by geologists to have originated in faults or dislocations caused by great dynamical agencies connected with extensive movements of the earth's crust; and for this reason they are believed to extend indefinitely downward; an assumption which is supported by facts, since no well-developed and defined vein has ever been found entirely terminating in depth. Gash-veins, on the other hand, as before remarked, occupying fissures which have resulted

from shrinkage of the rock, can not be expected to extend into strata of different character from that of the bed in which they originated.

Among all the forms in which the metalliferous ores occur, that of true veins is of much the greatest interest, since they are the principal repositories of the ores of the useful metals, and their exploitation is a matter of lasting importance, involving the employment of both skill and capital; hence their principal features require to be described somewhat in detail.

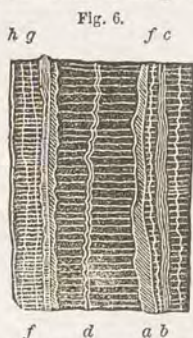
The linear extent of true veins is very various in different instances. Some of the longest known have been traced many miles; but usually, even if they extend for so considerable a distance, they are not found to be impregnated with ore through the whole of their course. The longer the vein, as a general rule, the more likely it is to be, in some part of its course, rich in ores: thus some of the great veins of Mexico, which have produced such enormous quantities of ore, have been followed for more than six miles, and have been opened and worked in a great number of places. The width of a vein is not necessarily in relation to its length; some, which are well-defined and traceable to a great distance longitudinally, are quite narrow. From the nature of their origin, their direction and dimensions must be somewhat irregular, since the two portions of the rock on each side of the original crack having been moved in relation to each other, the uneven sides of the fissure will have given rise to cavities of unequal width. That such motion has taken place, is abundantly proved in numerous instances by the actual displacement of strata or mineral masses once evidently continuous, and now removed to a greater or less distance from each other, both in a vertical and a horizontal direction. Such cracks frequently exist in the stratified rocks, and have not been filled up with mineral and metallic substances; in such cases, when there has been a perceptible vertical movement of the two sides in regard to each other, the break of continuity is called a "fault."

Fissures thus formed may have been the receptacles

of mineral matter unconnected with any metalliferous ores, as in the case of dykes of trap or veins of granite, which are usually considered to have assumed their present condition while in a plastic state. The filling of cracks in such cases was a process of short duration compared with the time required for the formation of veins containing metallic matter. In other instances there may be regular veinstone accumulated between the walls of a fissure, and yet ore be entirely wanting; but it is rare that this is the case, since in almost every vein in which mineral matter has slowly gathered, there have been metallic substances present in some part of its course, during some part of the time of its formation.

In regard to the occurrence of true metalliferous veins there is no fact more striking than that they are rarely found singly, but rather in groups, often in a complicated network crowded into a comparatively narrow space. The great mining regions occupy but a small part of the earth's surface; while very extensive tracts are almost wholly destitute of metalliferous indications. Let any one take a map of Europe and color upon it the best

known mining districts, which furnish the larger portion of the metals to commerce, and he will be astonished at the small space which they cover. The groups of veins of the Cornish and Saxon mining districts are so complicated in their number and variety of relations to each other, that centuries of working upon them have not yet fully developed even the more important facts with regard to them.



a, Bisulphuret of copper and sulphuret of zinc; *b*, comb of quartz; *c*, wall of indurate argillaceous matter; *d*, comb of quartz, with blende and copper ore (*f f*) on both sides; *g*, cavity, or vug, in another comb of quartz; *h*, more solid comb of quartz.

The various minerals which make up the body of the lode are frequently arranged in a succession of plates parallel to its walls. Usually these plates or combs, as they are called, are made up of aggregations of crystalline matter, the separate crystals of which have their axes at right-

angles to the wall of the lode, and are developed on the side turned toward its center. The annexed figure (Fig. 6) represents part of a lode at Wheal Julia, near Binner Downs, in Cornwall.* In this, which furnishes a good example of a comby structure, we see a central predominating mass of crystalline quartz, (*e*.) on each side of which are seams of copper ore, (*f f*.) This constitutes the main body of the lode. Between this central comb and the walls are two smaller combs of the same material, on each side, separated, in one instance, as seen at *c*, by a partition of earthy matter. Each comb consists of two corresponding portions, whose crystalline faces meet and interlock toward its center.

The larger portion of the vein-fissure is occupied almost invariably by the gangue or veinstone. This is the earthy or non-metallic portion of the lode or vein, consisting of mineral substances, of which a few are of almost universal occurrence as associates of valuable ores. The principal one of these is quartz, which may be said to be almost never absent entirely from any vein. It occurs in a great variety of forms, usually more or less crystalline, sometimes beautifully so, especially in "vugs," or cavities of the vein. Next to quartz, carbonate of lime is most common, in the form of calcareous spar, sometimes compact and sometimes crystallized, and often passing into brown-spar and dolomite. Fluor-spar and heavy spar are also minerals of frequent occurrence as veinstones. Sometimes these substances form the entire mass of the vein for some distance, either singly or together, and are completely destitute of metallic ores; but this is not usually the case.

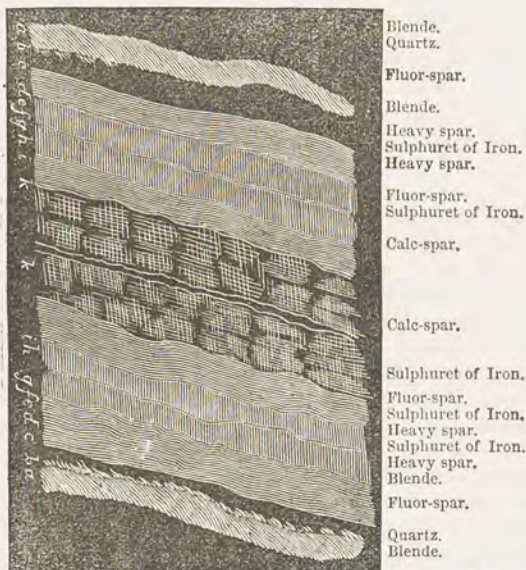
These appearances indicate a long-continued chemical action, occasionally broken off and then renewed; the materials held in solution within the space of the vein, or gradually segregating from its walls, varying in character at different times. Sometimes a fissure may have been reopened, after having been once filled up with mineral matter, and may thus have afforded space for

* De La Beche's Geo. of Cornwall, p. 240.

another deposition of veinstone. There are cases where this enlarging cavity of the vein seems to have been repeated, at intervals, several times in succession, the thickness of each comb indicating the width of the fissure at the time of its deposition, crystallization commencing on the walls as bases, and developing toward the center, until the whole space was filled up.

In other comby lodes the width of the fissure remained the same, and a succession of deposits took place against its sides, the nature of the material varying at different periods, so that a section of the lode shows a series of various mineral substances arranged in corresponding parallel layers on each side of the center. A beautiful instance of this mode of filling a vein-fissure may be seen in the annexed figure, (Fig. 7.) from Weissenbach's

Fig. 7.



Fragment of the Drei Prinzen Spat Vein, near Freiberg.

Illustrations of remarkable Vein-Phenomena, which represents a fragment of the "Drei Prinzen Spat" vein, near Freiberg, in Saxony. Next to the walls, on each side, is a crystallized deposit of blende, (*a a*;) to this succeed layers of quartz, followed by others of fluor-spar, sulphuret of iron, and heavy spar, as indicated in the figure, each comb on one side having one exactly corresponding on the other, while the middle portion is occupied by crystallized calc-spar, with a cavity in the center, the whole showing eleven symmetrical repetitions of six different mineral substances. Such perfect symmetry is, however, not often met with, and frequently the whole mass of the vein seems to have been formed by one uninterrupted process.

Every mineral district seems to have certain vein-stones, as well as ores, in a measure peculiar to itself, and the locality of an ore may frequently be recognized by a simple inspection of a fragment of the accompanying gangue.

Besides the veinstones proper of a lode, there are frequently found inclosed in it, fragments of the adjacent strata or wall-rock, which have been introduced mechanically. These may have fallen, in some cases, from the surface, or in the formation of the fissure the rock may have been crushed and broken into fragments, which have afterward been cemented together by the gangue, so as to form a brecciated vein. The fissure itself is frequently of a complex character, forming parallel branches, and sending out ramifications from the main line of fracture. Sometimes these strings are so numerous and irregular, that the main fissure becomes lost, and can no longer be recognized by the miner. When a large mass of the wall-rock is thus inclosed between the branches of a vein, it is called by the miners a "horse," or the vein is said to "take a horse." The vein-fissure is sometimes abruptly contracted, so as to show nothing more than a simple crack; in this case it is said to be "nipped." The branches which leave the main lode are called "droppers," and when they concentrate or fall into it again, they receive the name of "feeders." The direc-

tion and appearance of these off-shoots are closely watched by the miner in opening an untried vein, and from them he forms an opinion as to what parts of the lode are likely to prove richest in ore.

The mass of the veinstone is usually separated from the wall, by what are called selvages, (French, *salbandes*; German, *saalbänder*.) These are usually thin bands of clayey matter, and are of importance, since they prevent the adherence of the lode to the wall-rock, and of course facilitate its removal. The walls of the veins themselves are frequently smoothed and striated, as if there had been motion of the lode on its wall, accompanied by pressure; these polished surfaces are called slickensides.

The annexed ideal section of a part of a vein (Fig. 8) will serve to convey an idea of the various technical terms used in speaking of a vein, and its connection with the rock. Cornish miners having been first and most extensively employed in this country, their terms have been generally adopted, as they are in England, from the fact that Cornwall is the most extensive mining district in that country.

It has already been noticed, that the metalliferous portion of a lode, or the really valuable ore, makes up, usually, but a small portion of its contents. The barren or worthless mineral substances extracted from the lode and from the adjacent rock, in the process of removing the vein, are called *deads* or *attle*. But few veins are sufficiently rich throughout the whole extent of the mine in which they are worked to allow of their being removed entirely. Frequently a large part of the lode is left standing, or unexcavated, while only the rich bunches of ore are taken out and raised to the surface. The occurrence of these rich deposits of ore in a vein is a matter of great uncertainty, and can only be judged of by the miner, after a careful observation of the district in which he is working. Some varieties of rock, or strata of peculiar mineralogical character, may be found in certain districts particularly rich in ore; and in such cases the right kind of country will be sought for by the

Fig 8.



Transverse section of a vein.

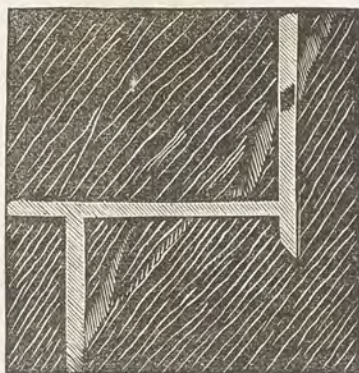
a a, country; *b b*, vein; *d*, hanging wall.
c, foot-wall; *e e*, selvage; *f*, vug; *g*, horse.

miner, and the workings on the veins developed to as great an extent as possible in that rock. In other regions, when there are numerous parallel or similarly situated veins, the run of the courses of ore (their situation in regard to the vein) having been determined in one case, the same rule may be found to apply to others. The differences in the character of two rocks, one of which may be highly favorable to the development of a rich lode, and the other just the contrary, are often not of a kind to be easily expressed in words. Long practice and a well-trained eye will be required, to decide at once which presents the most favorable appearance. Nor does the same rule seem to hold good in different districts, for the formation which in one is productive, will sometimes be found barren in another. Hence miners, with certain fixed ideas, derived from the obser-

vation of a limited district, are apt to be led entirely astray, when they insist on applying the same rules to another mining region.

Since the crevices occupied by veins have resulted from the dislocations of the rocks in which they occur, and since their formation has not been confined to any particular epoch, it follows that there may be in any one formation a variety of fissures of different ages and directions. This is found to be the case in many important mining regions, and the phenomena resulting from their influence on each other are often of great interest. The direction of a vein may sometimes be altered suddenly by a change in the course of the fissure, without being heaved out of its course, as it is termed by the intersection of another. Thus, in the annexed cut, (Fig. 9.) which

Fig. 9.



Section of a vein at Holzappel.

represents a transverse section of a vein at Holzappel, in Baden, where the vein coincides in dip with the strata, and has been shifted from one plane to another, a distance of twenty-five or thirty feet, without any dislocation having taken place in the rocks; the fissure still connected the two portions of the vein, but was so indistinctly marked that the level was driven through it, as shown in the figure, without its having been perceived; and it was only found again by sinking, when it was struck, having the same characteristics as before.

In a similar manner a true fissure-vein may at some part of its course seem to coincide with the dip of the strata, and actually send out branches which follow the

lines of dip or cleavage; and yet the main fissure may pursue its course across the lines of bedding, although only cutting them at an acute angle, as represented in the section, (Fig. 10.) In such a case it may not be possible, without sinking upon the lode for some distance, to ascertain its real character as a true vein. The branches, which are parallel with the stratification, may be regarded as occupying fissures subordinate to the main one, which have been opened along the line of easiest fracture.

Fig. 10.



Veins sending out branches which coincide with the bedding of the rock.

The derangements caused by veins of different ages and directions crossing are of great interest. If a vein traverses an older one, it interrupts its continuity, and frequently heaves it to one side or the other. Two systems of veins thus crossing each other, may in their turn be both intersected by a third and still newer one, which may heave the other two. Instances of this kind are common in mining districts which have been subject to frequent dislocations. The newer vein intersecting an older one at a considerable angle is called a "cross-course," or contra-lode; the latter name being usually applied to the intersecting vein, if it contain valuable ores. In Cornwall, there are several systems of fissures, producing in many instances a complicated shifting of the veins. The general parallelism of veins of the same age is remarkable in many parts of that region, and generally in all districts where there are numerous fissures of different ages. It is also noticed that contemporaneous veins are not only parallel with each other, but

that they usually contain the same varieties of ore associated with similar veinstones. In the Harz, there are two principal directions of fracture; the Samson, the most powerful lode of the district, cutting and heaving the Gnade Gottes and Bergmann's Trost, two other important veins. The most interesting and complicated phenomena of the intersection of numerous systems of veins are presented by the Freiberg district in Saxony, where extended mining operations have been carried on for a great length of time, and have been studied by a skillful corps of mining engineers and professors attached to the School of Mines at that place. More than nine hundred different veins have been recognized within a space of ten or eleven miles in length, by four or five in breadth. They are grouped by Weissenbach into four classes, according to the nature of their gangues; each of which is also in some measure characterized by certain ores, and by a constant direction.

In this country there have been no such complicated phenomena of veins of different ages observed. In the region to which most properly the term mining district may be applied, namely, that of Lake Superior, there are numerous veins, but they do not afford evidence of more than one epoch of formation. In any limited district, as, for instance, that of Keweenaw Point, the veins are nearly parallel with each other, and are not intersected by cross-courses, which heave them from their course. In a few instances there seem to have been slips of the various beds of rock upon each other, which have shifted the veins at the junction for a few feet to one side or the other. In the Southern States the metalliferous deposits usually lie in the direction of the stratification, belonging to the class of segregated veins, and are not crossed by any fissure veins. It will not, therefore, be necessary to go into any lengthy description of the particular appearances attendant on such intersections, especially as they differ much in different districts. In general, however, the crossing of two veins is wont to be considered as advantageous to the production of ore at that spot, and rich bunches of

mineral are looked for by the miner at their intersection, especially if the angle at which they meet is a small one. Sometimes one lode impoverishes the other for some distance, carrying all the ore with it. As an instance of this appearance presented by two lodes intersecting each other, the annexed cut (Fig. 11) is given, repre-

Fig. 11.



Ground plan of the intersection of veins in the Himmelfahrt mine, near Freiberg.

senting one lode crossing another as sketched by Weissenbach.

Theories of the Formation of Mineral Veins.—Although a full discussion of the various theories of the formation of the metalliferous deposits would occupy much more space than can be given to the subject in the present work, yet it will not be out of place to notice briefly some of the most important theoretical considerations which the study of vein-phenomena suggests. The following are the principal heads under which the theories which have been proposed may be arranged.

1. The veins originated contemporaneously with the rocks in which they are contained, and are, so to speak, a mere accidental phenomenon, not governed by any fixed laws of formation. This theory may be dismissed at once, as entirely at variance with all the facts, and as unworthy of consideration.

2. Veins have originated in the filling of fissures, by injection of metallic and mineral matter in a state of igneous fluidity from below. This is the theory usually adopted to account for the phenomena of the veins of so-called igneous rocks, such as granite and trap; which, like modern lava, are supposed to have been once in a plastic or semi-fluid state, under the influence of a high temperature, and in such condition to have invaded the superincumbent rocks, being forced into the crevices by upward pressure. However such a theory may adapt itself to the Plutonic veins, it can not be considered as explaining the modes of formation of metalliferous lodes. It fails to account for, or rather is contradicted by, the often observed fact, that the character of the lode changes with the rock in which it is found, being rich in ore in one formation, and barren in another adjacent one. This could not have been the case if the vein had been forced up through the strata, as the nature of the rocks through which it was raised could have had no influence on its contents, the action being but momentary and mechanical. Besides, if we consider the immense force which must have been required for such an upward motion as this theory supposes, it will be apparent that, had it really taken place, evidence of its existence must have remained in the widening out of fissures in depth, and in the shattered condition of their walls; while there would have been a constant tendency in the more valuable metalliferous substances, being heavier than the veinstone itself, to occupy the lowest position in the vein. Such phenomena, however, have only been observed in isolated cases, while usually the appearance of the walls and the distribution of the mineral matter and ore between them in true metalliferous veins, is such as to make this hypothesis of their formation entirely untenable.

3. The theory of formation by sublimation, according to which vein-fissures were filled by the volatilization of metallic matter from the great centre of chemical action beneath, namely, the ignited interior of the earth. That such might have been the origin of some metalliferous deposits, and that this agency may have contributed in some degree to the filling of veins, cannot be denied. The fact of the volatility of some metallic combinations is well known, and can be observed at the present day in the products of volcanic ejections. Evidence of the same character is afforded, in some instances, by the position of metalliferous particles on the under side of crystals lining the walls of a lode; as, for instance, Nagyag, in Transylvania, where metallic arsenic is seen to have been sublimed and deposited on those faces of crystals of manganese-spar which were turned downward. Specular iron is found sublimed into the fissures of volcanic craters, and sometimes carried to a considerable distance and deposited. But these phenomena are of limited extent, and not by any means sufficient to account for the existence of the masses of ore and of earthy minerals filling the body of a large vein. Neither would such a theory account for the variation in the character of lodes in passing from one rock to another, nor for the presence in them of substances not volatile in their nature, nor for any of the complicated phenomena exhibited by veins in their intersections with each other. Hence we must conceive that the agency of sublimation was of very secondary importance in the formation of metalliferous veins. In contact deposits and some irregular forms of occurrence, where the whole mass of a bed seems to have been impregnated equally throughout by metallic particles, as especially exemplified in some mercury mines, we can conceive of no theory more probable than that of the diffusion of the metallic matter through them by sublimation. Thus originated the extensive beds worked at Almaden, so rich in mercury; and they offer the most striking example which can be given of the class of deposits to which this theory may be applied.

4. The theory proposed by Werner, which may be called that of aqueous deposition, presupposes a chemical solution covering the region in which the veins are found, from which solution, by chemical precipitation from above downward, the vein matter was accumulated in the fissures existing in the rocks below. This theory is in direct opposition to that of igneous injection, since, according to its principles, the origin of the contents of veins was a superficial one, their introduction into the fissures from above instead of from below, and the action a chemical instead of a mechanical one. But in the sense in which this mode of formation was understood by Werner, but little importance can be attached to it. If any such fluid holding metalliferous substances in solution had actually covered the surface, we can conceive of no reason why it should have deposited its contents in the fissures rather than on the surface adjacent; and we ought, in accordance with his ideas, to find every vein connected with a flat sheet of metalliferous ore somewhere along its course, at the place which the solution occupied in the series of formations at the time of the filling of the vein-fissure. Such, however, is not the case, at least in regard to true veins, although there may be a limited class of mineral deposits to which this theory will apply. Besides, if depositions in veins took place in this manner, we should expect to find more or less matter introduced at the same time, mechanically, and showing its origin by its stratified condition. There is nothing of this kind, however, observed in true veins. The deposits all took place in a direction parallel to the walls, and not horizontally, as they would have been in part, under the circumstances required by this theory. There are many other reasons equally conclusive against the ideas of Werner; but it is not necessary to enter into them at length, since his theoretical views with regard to the origin of veins have ceased to have the weight which was once attached to them.

5. The theory of lateral secretion. The views which are at present most generally adopted, assume a somewhat complicated series of phenomena as concurring in

the formation of mineral veins. It cannot be doubted that the process has been a complex one, and one requiring a long period of time for its development. No one simple cause can be considered sufficient to account for all the facts; but the main idea is that of lateral secretion, or segregation of the mineral and metalliferous particles from the adjoining rocks in a state of chemical solution, and their deposition upon the sides of a previously formed fissure under the influence of electro-chemical forces.

This is the only theory which will account for the often-noticed fact of the change in character of a lode in passing from one geological or mineralogical formation to another of a different character, and it seems to be more in accordance with the other phenomena of veins than any other one yet proposed.

The metallic appearance of the most common ores, and their resemblance to certain well-known furnace products, are apt to lead to the supposition that they must be exclusively of igneous origin, especially in view of the fact that the mineralizing substances with which the metals are generally found combined are such as have the effect of rendering them more volatile. Nor can it be denied that some ores and metals do occur in rocks of undoubted igneous character in such a way that they must have had an origin contemporaneous with that of the mass in which they are disseminated. But these deposits do not belong to the class of regular veins, in general, but are to be classed, as already shown, among the irregular modes of occurrence. The metalliferous substances produced artificially, and found filling cracks and cavities in connection with furnaces, and in the chimneys of smelting-works, do not seem to possess that comby structure, or parallel arrangement so characteristic of true veins. If metalliferous particles were introduced into a vein-fissure by sublimation, they would naturally rise and be condensed together in accumulated masses, which might have a crystalline structure, but would be distributed in such a manner as to show their igneous origin.

On the other hand, we know that the earthy substances forming the gangue of metalliferous lodes, and usually far predominating in quantity over the ores themselves, are not the products of igneous action. The minerals which form the mass of the trappean rocks and of volcanic lavas, such as the feldspar family, hornblende, augite, olivine, and the like, are not the usual components of the veinstones, as we should suppose would have been the case were the veins in which they occur the result of igneous action. On the contrary, we know that the usual gangue minerals, quartz, calcareous spar, and heavy spar, according to the researches of Bischof and other eminent chemists, can not possibly have been introduced into vein-fissures by injection while in a state of igneous fluidity, or by sublimation. We know also that some of the ores accompanying these veinstones undergo decomposition at a high temperature; and many of the most common, such as sulphurets of iron and lead, we see in constant process of formation in aqueous solutions, at the present time. The sulphuret of iron is one of the most common products, where ferruginous waters are brought into contact with decaying organic matter; and it is also one of the precipitates from hot springs. It has been shown by Murchison that the copper ores of the Permian strata of Russia must have originated in a similar way, since they are accumulated around and on the surface of the carbonized remains of the stems and branches of plants.

Fissures being opened far down into the heated interior of the earth, they would become filled with water charged with various kinds of mineral and metallic substances. In their passage through rocks of various characters, these solutions would be variously acted on, and would, under hydrostatic pressure, penetrate more or less deep into the surrounding strata, according to their texture and other circumstances. If the water was acidiferous, it might thus combine directly with metalliferous particles previously existing there.

There can be no doubt that the contents of a vein-fissure have often acted chemically upon the adjacent

rocks, since it is very frequently found that the walls have undergone a great change for a considerable distance from the lode; often the country is found decomposed and rotten, its texture being entirely destroyed; or it is impregnated with silicious matter, so as to be much harder and more quartzose than at some distance from the lode. These hardened silicified masses are called by the Cornish miners the *capels* of the lode.

Under the presupposed circumstances, it is evident that a fissure being filled with solutions thus originating, there would be ample reason why there should be deposits of ore within the limits of certain strata, in preference to others. Either those beds might themselves contain more metalliferous substances, which would enter into solution, to be again deposited within the walls of the fissure, or there might be something in their structure which would enable them to act with more efficiency in decomposing the solutions brought from other sources, by circulation of the column of water filling the cavity of the vein.

We cannot doubt that electro-chemical action is and has been going on in mineral veins, and that the explanation of many of the more obscure facts with regard to the distribution of the ores within them is to be found in this all-pervading agency.

Mr. Robert Were Fox seems to have been the first to be impressed with the idea that electric currents might "not only contribute to produce the extraordinary aggregation and position of homogeneous minerals in veins," but that the action was still kept up in them, and he instituted a series of experiments in the Cornish mines for the purpose of determining this fact. He found the mine-waters to be impregnated with a variety of salts, but in very different proportions in different parts of the same mine. He also found, by numerous experiments, that the reaction of these solutions on each other, and their contact with extensive surfaces of rocks of different characters, gave rise to electrical currents, the effect of which was to promote decomposition and deposition of various mineral substances, similar to those

found occurring in veins. He thus was enabled to account for some of the most curious facts in relation to the position of the ores in the Cornish mines. Professor Reich, in the Freiberg mines, arrived at similar results, and Mr. Robert Hunt also made numerous experiments, determining the existence of galvano-electric currents in the veins of Cornwall, and producing chemical decomposition by their aid. He arrived at the conclusion that these currents were purely local in their nature, originating in the decompositions going on in the vein itself, and not connected with the great magnetic forces which sweep around the earth.

Whether or not it be allowed that these electro-chemical currents performed a very important part in the original formation of veins, it can not be denied that in the chemical changes which have taken place in the upper portions of metalliferous lodes, and which are evidently still going on, they were and are conspicuous agents. These changes of character are well recognized in all mining districts. They are usually indicated on the surface by a discoloration of the lode by oxyd of iron, and a general rotten appearance of the veinstone. The Germans call this the "iron hat" of the vein; the Cornish give to it the name of "gossan."

In the cupriferous lodes of Cornwall, the normal ore, below the point to which decomposition has reached, is copper pyrites, or sulphuret of iron, and copper, and other sulphurets of copper. But near the surface, the metalliferous ores, instead of sulphurets, are oxyds and oxydized compounds, such as silicates, carbonates, and phosphates. Often a large portion or all of the copper near the surface has been removed, having been oxydized to sulphate of copper, and dissolved out and washed away, leaving the iron mixed with the quartzose veinstone, in the form of a hydrated oxyd or gossan. Similar appearances are presented by lodes containing lead ores, the sulphuret of lead, or galena, which is almost the only ore found in any considerable quantity at some depth, being, near the surface, converted into a great

variety of oxydized combinations, of which the carbonate, sulphate, and phosphate are the most common.

In general, this zone of decomposition does not reach much below one hundred feet, but in some instances it penetrates to the depth of three hundred, and there are, on the other hand, veins in which no such chemical changes have taken place, the original sulphurets existing undecomposed almost at the very surface. The causes which have operated in accelerating and retarding these transformations are not quite clearly understood. Bischof has shown that heated steam has been one of the most powerful agents in the decomposition of the contents of veins, and that it has been most effectually aided by carbonic acid.

In order to prove this, he subjected sulphuret of lead, while heated, to the influence of a current of steam, which reduced the galena to metallic lead, the sulphur passing off in the form of sulphydric and sulphurous acid gases.

Sulphuret of silver is reduced in the same way, the resulting metal taking that dendritic form which it commonly has in its associations with the ores of lead and silver. The reduced metals thus set free, if they belong to the oxydizable class, are then ready to enter into combination with the various acids everywhere being liberated under electro-chemical agencies. No doubt the effect of atmospheric influence is to be largely taken into account also, since these changes are principally superficial only, compared with the total depth to which the ores are found to extend. The penetration of water charged with oxygen into the fissures and minute pores of the rocks must be in some degree essential to these processes. To give any idea of the complicated changes thus slowly taking place in many lodes, would require far more space than the object and scope of the present work could permit; it is sufficient here to have indicated some of the causes at work in the formation of mineral veins.

The variations of the metalliferous portions of lodes at different stages are of the highest importance to the

miner, not only in relation to the changes which the ores have undergone near the surface, but as viewed in connection with their persistence in mines worked to great depths. In this country we have hardly more than begun to open our mines, so that we have but little more than superficial indications to judge from; but in the mining districts of Europe, which have been wrought for centuries, there are abundant data accumulated to enable us to draw some important conclusions in regard to the termination of veins in depth. The distinction between true veins and all other forms of occurrence of ores must be carefully studied in reference to this question, or otherwise it will be difficult to obtain a clear conception of the truth. The facts may be briefly summed up thus:

1. True fissure-veins are continuous in depth, and their metalliferous contents have not been found to be exhausted, or to have sensibly or permanently decreased, at any depth which has yet been attained by mining.

2. Segregated and gash-veins, and the irregular deposits of ore not included under the head of veins, and not occurring in masses as part of the formation, can not be depended on as persistent, and they generally thin out and disappear at a not inconsiderable depth; at the same time they are often richer for a certain distance, and contain larger accumulations of ore, than true veins, so that they may be worked for a considerable time with greater profit than these, although not to be considered as of the same permanent value.

THE GENERAL PRINCIPLES ON WHICH THE CONTENTS OF A VEIN OF MODERATE WIDTH ARE REMOVED.

In order to render the descriptions of mines and mining operations in the succeeding chapters more intelligible to those who have never given their attention to these subjects, it is proposed to add a few pages on the general principles of exploitation; by which term is understood the process by which ores and minerals of value are won from their natural position, often at great depths

below the surface, and brought where they can be rendered available. Those who are not acquainted with the nature of such operations, and who have never had occasion to reason on the many circumstances which must be taken into consideration in laying them out, frequently suppose that a mine is a mere excavation in the ground, without law or rule, and that this, which would seem to them to be the simplest method, would be also the best for such a work. Nothing can be farther from the truth; for to open a mine, if on a vein or regular deposit of ore, and work it as an excavation open to the air, or as an "open-cut," is quite impossible, if it is necessary to go below the most moderate depth. And such is the case with metalliferous lodes, the superficial portion of which, for some distance down, is often less valuable than that below, and sometimes of no value at all. Moreover, the richest part of a vein is usually of limited extent, and its treasures can only be won by penetrating into the earth to great depths. To raise the ore from such a distance beneath the surface, requires powerful machinery, which must be placed on firm ground directly over the vein. The surface-water and rain must be kept from running into the excavations, which could not be done were they opened throughout to the day; and as the freeing of a mine from water is one of the most expensive operations connected with its working, the greatest care should be taken to get rid of as much as possible in the simplest and least expensive manner.

Again, it is necessary that mining should be carried on uninterruptedly by night and day, and in all weathers, since only a limited number of persons can be usefully employed at one time; also that a system of ventilation should be kept up; all of which would be impossible, were the excavations exposed to the weather, or the mine made to consist of a single open cavity.

The first operation in opening a mine is usually to remove the surface-water, by driving an *adit-level* or horizontal gallery, which shall commence in an adjacent valley, at the lowest point not liable to inundation and con-

veniently accessible, and thus drain all that part of the proposed work which lies above.

Fig. 12.



Transverse section of a shaft and adit-level.

Figures 12 and 13 illustrate the position and object of the adit-level. In extensive mines large sums are frequently expended in thus getting rid of the water; sometimes a number of mines are drained by a simple adit of great length driven at their joint expense, or that of the state, when the work is of great magnitude. So long as the excavations in the mine are kept above the level of the adit, no machinery for pumping is required; and when extended in depth below it, the water is elevated by the pump or other contrivances employed, only up to that point. Thus, in a very extensive mine, every foot through which a large body of water is to be raised, which can be saved, is of importance, and large sums of money may be economically expended in obtaining even a small reduction of the distance.

Frequently only a few feet of "back," as it is called, or of perpendicular height above the adit-level, can be obtained; but in other cases, by an adit planned with judgment, several hundred feet of drainage may be obtained, so that mining may be carried on for a long time without the expense of costly machinery for pumping. If possible, the adit should be driven on the vein, or by the side of it, so that its character and richness may be ascertained by breaking into it occasionally as the work progresses. A large number of the Lake Superior mines are thus favorably situated; and extensive drainage may be had at the same time that the vein is proved in depth.

If sufficient advantages present themselves for the location of machinery for washing and dressing the ores at the mouth of the adit-level, they may be brought out on a tram-road laid in the level, and the necessity of hoisting them to the surface by machinery may be thus obviated. If the adit-level can not be excavated *on* the vein, it must be driven *to* it, as represented in Fig. 12, and the levels are then to be extended on it right and left.

In a region where the veins run in a direction parallel with the range of elevations, it will generally be necessary to drive the adit-level through the "country;" but if the vein crosses the ridges at an angle, it will also cross the nearest valleys on each side of the elevation, and may be worked from one side or the other. In the majority of cases, however, the adit-level is only used to remove the surface-water, but few mines being so favorably situated as to have a very large portion of their work above it.

As the necessity of ventilation would not allow the adit-level to be driven to an indefinite distance without some communication with the surface, so as to establish a current of air through it, it becomes necessary to commence excavations on or near the line of the veins, which may intersect the adit, or a cross-cut or level leading from it, and which are carried down to a still greater depth for the purpose of opening and working the mine. These excavations, whether vertical or inclined, are called shafts. Their inclination depends on a variety of circumstances, such as the underlay of the vein, or the angle which it makes with the perpendicular, its width, or the nature of the rock in which it occurs.

If the vein approach a vertical position, the shafts are usually sunk upon it, unless its underlay is so irregular as to spoil the shaft, by making it too crooked, in which case it is sunk by the side of the vein, and connected with it by cross-cuts. In Fig. 12, a shaft thus sunk on a vein of generally regular underlay is represented. Whether a shaft shall be sunk on the vein, so as to include the vein within it, or by the side of it, is also de-

pendent on some other circumstances. If the lode is wide, and the veinstone such that it can be wrought with as much facility as the adjoining rock, it is best to sink in the vein itself, especially when its dip is nearly vertical, and the country solid, so that little ground need be left standing in the lode to support the walls and preserve the shaft. In the mines of Lake Superior this method is generally followed.

If the vein has an underlay as great as forty-five degrees, it is a matter of some importance to know whether it is best to work the mine through shafts inclining with the vein, or by vertical shafts connecting with it by cross-cuts. The latter method is illustrated by the annexed ideal section, (Fig. 13.)

Fig 13.



Ideal section of a system of shafts for opening a mine on several parallel lodes.

In such a case, a shaft is commenced at some distance from the lode, in the direction from its outcrop toward which it dips, and sunk perpendicularly until it cuts the lode, at a point the depth of which can be calculated if its dip is known. After intersecting the lode, it may be continued below it, and cross-cuts must be driven as before, at suitable distances, so as to open a sufficient number of points for working. If there are several different lodes within a small space, as represented in the figure, or if it is desirable to make underground explorations for veins not supposed to appear at the surface, the method of sinking vertical shafts is to be recommended.

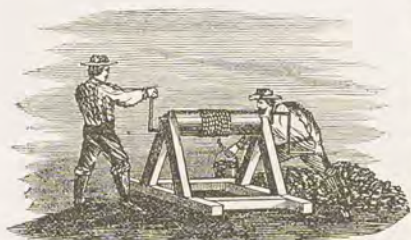
In the English mines the practice of sinking shafts inclining with the lodes, has not generally been adopted; although, when it can be done, it presents some great advantages over the other method, a large amount of unprofitable excavation in the rock, or *dead-work*, as it is called, in cross-cutting from the shaft to the lode, being thus saved. This method may be recommended when the dip of the lode is tolerably regular and the

rock solid, and where there is only one vein to be worked through the same shaft. In order to raise the ore in such a case with advantage, a double tram-road should be laid in the shaft, and the ore hauled up in cars which run from the levels directly on to small platforms, mounted on wheels, on which they are raised to the surface. In the Lake Superior region there are numerous veins underlaying from forty to fifty degrees; the shafts are invariably carried down on the lodes, and no practical difficulty experienced; on the contrary, it has proved the most economical and judicious method under the circumstances. In the Southern gold mines, where the rocks are frequently decomposed and softened, so that for the first fifty to one hundred feet sinking costs but little, the shafts are generally vertical. Of the gold regions of the Pacific coast the same may be said. If the underlay of the lode is very irregular, it is better not to sink upon it, as crooked shafts present many disadvantages in fitting up the machinery for pumping, tram-roads, and other requisites.

The dimensions of a shaft are variable, and dependent on the work to be done by its aid. When it is to be used for winding up the kibbles, or buckets of ore, and at the same time as an "engine shaft," or the shaft in which the pumping machinery is placed, it should be from twelve to fourteen feet long, and is usually from six to eight feet in width. Shafts which have been timbered up for the whole or a portion of their length, are square or rectangular; those which are built up with stonework are usually round.

In this country, wood is universally used for this purpose, timber being usually cheap and abundant in our mining districts. In the Lake Superior region, the shafts only require to be supported for a few feet, or until solid rock is reached. The timbers are squared roughly, and laid upon each other, forming a substantial framework, which rests in a bed-place cut in a rock, where it is sufficiently solid to obviate any danger of its giving way.

For a distance of fifty feet, or even one hundred, if desirable, the ore and rubbish may be raised to the sur-



face by the simple windlass, worked by hand. The same means are used in sinking a "winze," or excavation from one level to another, not extending up to the open day. As soon,

however, as the depth of the shaft becomes more considerable, it is necessary to resort to horse or steam-power for raising the ore. The common machine used for this purpose is called a whim. As usually constructed when worked by horse-power, it is represented in the annexed cut, (Fig. 14.) In the steam-whim, which is generally used when the shaft has a depth of more than two hundred feet, the cage or drum on which the rope or chain is wound is usually placed horizontally, instead of vertically, as in the common horse-whim. Frequently, in opening a mine, before the excavations have reached any considerable depth, the pump-rod is attached to the whim, and worked by the same power which raises the ore.

The steam-engine is not usually applied to working a mine until there is good reason to suppose that it may become of permanent importance. For hoisting ores, no very great power being



Fig. 14. Horse-whim.

required, small horizontal high-pressure engines, working full steam, are usually employed. The machinery must admit of instantaneous reversal, and should be as simple as possible. Water-power, if at hand, can be advantageously applied to the same purpose. The pumping-engines in extensive mines are usually low-pressure ones, and every effort has been made in Cornwall and other mining regions to reduce the consumption of fuel to the smallest possible amount, by perfecting the form of the boiler and machinery.

Most mines, when worked to any considerable extent, have several shafts; two, at least, are almost necessary for ventilation. The distances from each other at which they are located depend on a variety of circumstances, such as the nature of the surface, the distribution of ore in the vein, and the extent of the set or length of the vein which can be worked. Two shafts should not be too near each other, if it can be avoided, as in that case the blocks of ground would be too short, causing a wasteful expenditure in opening the ground. If far apart, winzes must be sunk between them, in order to afford ventilation and the means of attacking the vein at a sufficient number of points. In general, three hundred feet distance between two shafts, in a vein of moderate width and richness, may be considered reasonable.

After the shaft has been sunk to a proper depth, if on the vein, drifts or levels are commenced from it in each direction, so as to open blocks of ground, as they are called, or portions of the vein, which are thus rendered accessible so that their contents can be removed. The Cornish miners usually arrange the drifts so as to leave between them a back of sixty feet, or ten fathoms—that is, one level being started, the shaft is continued sixty-six feet, (six feet being allowed for the height of the drift,) and then another level is commenced, leaving a portion of the vein between them sixty feet in height. Like the shafts, the levels may be driven in the vein itself, or by the side of it, according to its width, texture, and other circumstances.

The contents of a block of ground thus prepared are

removed by what is called *stoping*, or working in steps, the object of which is to take out all that portion of the

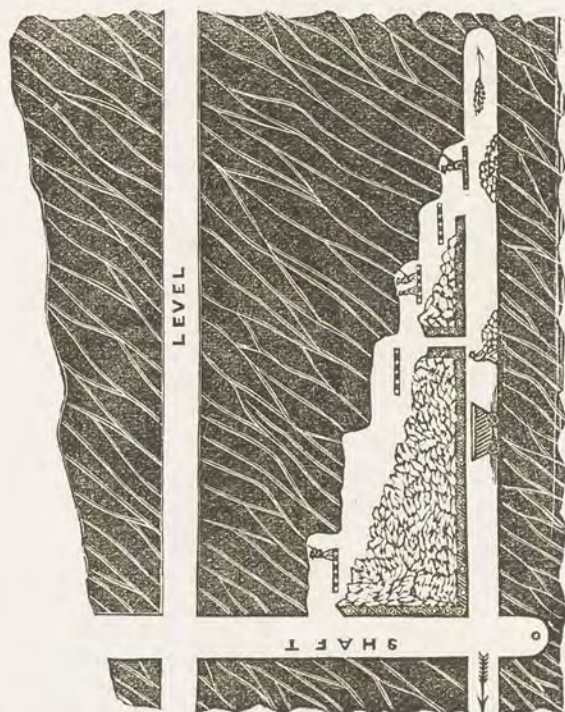


Fig. 15. Method of overhand stoping.

vein which is worth reserving for its ore. There are two methods of doing this, one of which is called overhand and the other underhand stoping, the difference being, that by the former method the vein is taken down by working from below upward; in the other, by excavations from above downward. Overhand stoping is almost universally practiced in this country.

The annexed section (Fig. 15) will illustrate this method. It represents a supposed longitudinal section, on

the vein, of a shaft and two levels, between which stoping is going on. The rubbish which is necessarily blasted down with the valuable part of the vein, is piled up back of the miner, as his work proceeds, on a scaffolding of

Fig. 16.



Timbering in a mine.

stout timbers, called *stulls*. At suitable distances openings are left through the rubbish, called *mills* or *passes*, through which the ore is shot down to the level below, to be loaded on to a wheelbarrow or car, and conveyed to the mouth of the drift, or to the shaft, to be hoisted to the surface. The rubbish accumulated in the space from which the vein has been removed serves to support the walls and keep them from coming together. The annexed cut (Fig. 16) shows, in a transverse section, the method of supporting the rubbish and the floor

of the level beneath. The workman, while engaged at stoping, stands on a platform laid on stulls, as indicated in Fig. 15 above. Stoping upward is the most rapid and economical method, when the ores are not very valuable, or difficult to distinguish from the rubbish. Of course, in working from below upward, the looseness and working away of the rock is aided by gravity, the fragments tending downward by their own weight, and it is therefore easier for the miner; but, on the other hand, as the rock and ore are thrown together by each blast upon the pile of rubbish below, it requires care, on the part of the miner, to select out the valuable portion of the lode without sending up too much of the worthless rock, which, apart from the cost of hoisting it to the surface, is needed to fill up the space left by the previous excavations, in order to help support the walls.

Fig. 64 shows the mode of working in the Gould & Curry mine, illustrating the driving, timbering, and hoisting, and exhibiting the tramways and cars employed.

The man in the left-hand corner is engaged in sorting the ore.

Exploitations of Thick Veins and Masses.—When the deposit of ore to be mined is in masses, or veins of extraordinary width, the process of removing their contents becomes a more difficult one, especially if the surrounding rocks are not firm and unyielding. The general method, however, is the same. The work must be subterranean and not open to the day. One or more shafts must be sunk into or near the mass to be removed, and the work commenced at as low a point as possible. Levels are then driven into the ore, and as fast as the valuable mineral is removed, the rubbish which is made is piled up in its place, so as to support the portion left overhead. If there is not enough material for this, stones must be sent down from the surface. In this way the whole contents of a mass can be removed without loss. The methods pursued in such workings must be especially adapted to the shape of the deposit of ore, the degree of solidity of it and of the adjoining rock, and a variety of other circumstances; the general principles, however, are those above indicated.

Timbering of Mines.—We now come to the timbering of mines, an important subject. In Mexico, stringent laws have long been in existence, and are strictly enforced, regulating the size of the pillars of ore, and their distance from one another, to be preserved in each silver-mine for the protection of the mine, and the adequate support of the superincumbent mass. There, these columns of ore preclude the necessity for timbers; but in California it is different. Here, nearly all our mines are auriferous; and instead of the deposit being a huge, deep mass of ore, it generally occurs in a single stratum. Besides, the rock is seldom compact enough to form supports.

Perhaps it would be as well if California also had laws regulating the timbering of mines; for the bungling and insecure work of inexperienced timberers has occasioned, in many cases, great damage to the mines, and even loss of life; and instances are not wanting of large tracts of

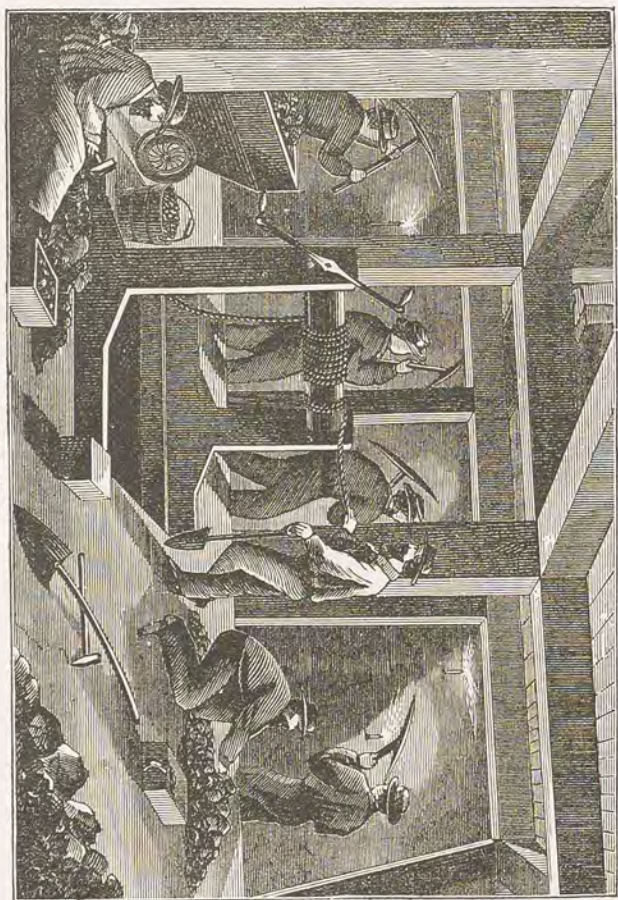


Fig. 16.



country, beneath which mines have been or are being worked, suddenly sinking, because the props or timbers were of bad material or shape, improperly or imperfectly adjusted, or unattended to for a course of years, and suffered to rot without being replaced by new ones. Thus the houses, gardens, and fields above were, in a great measure, ruined, as well as the mines below.

A large amount of wood is, of necessity, required about a mine, and great care should be taken in its selection. "In some mining regions," says Professor Whitney, "where it is scarce, its cost becomes one of the most considerable items of expense to be incurred, as, for instance, in the Australian copper mines. Cornwall is mostly supplied from Norway; and the timber cut from hundreds of square miles of Norwegian forests is now buried deep beneath the surface in the Cornish mines. In Germany, large tracts of forest are set apart for the use of the mining districts; and the wood is cut from a certain portion every year, so that a constant supply is kept up." Were such tracts of timber reserved in this State, perhaps it would be better for our mining posterity.

The timber most commonly used in the mines of California is pine, which grows in great abundance upon the mountains. It is far from being the best kind of wood to use for this description of work, but is the only kind universally handy. It should, by all means, be well seasoned, to avoid shrinkage, and the timbers must be placed pretty close together.

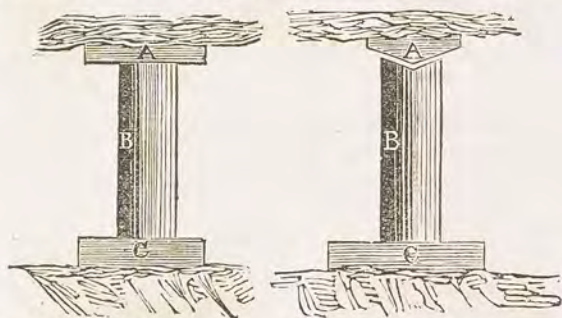
A very important and valuable machine, recently invented by Messrs. Denver & Hockholzer, of Gold Hill, built to run by steam-power, will prepare all kinds of timbers for mining purposes, at less than one sixth the present cost, and with perfect accuracy. The following is a description from specifications and plans: A sliding table, bearing the timber designed to be framed, run upon a wooden frame having ways in grooves beneath, and so regulated as to be forced to the front by a hand-wheel, pinion, and rack. The timber used being hewed, but not square nor of uniform thickness, is first properly entered and marked with a line of chalk, and then placed on the

frame in a circular iron band, and so adjusted with set-screws that the chalk-lines on the timber shall correspond with the lines marked at right angles, and through the centre of the circular iron band, which revolves in the standard, securely bolted to the iron table. After due adjustment of the timber, the band is fastened to the standard with an iron pin, and the timber is forced against the cutters; the timbers pass over the same. The cutters are made like ordinary planing-knives, and have an addition of a small circular saw, for cutting the square shoulder on the timber. The bevel-cutters are without the saw, and are placed at the end of a rapidly revolving shaft, so adjusted in brackets as to be raised or lowered so as to cut any sized tenon. The iron bands holding the timber revolve one quarter revolution at a time, at an angle of ninety degrees, without any displacement of the timber, thus cutting the same at an equal bevel on all four sides; again, after cutting the tenon, the timber is moved forward against the two circular saws that square the ends of the same, and the work is completed—no subsequent dressing being required, as in other inventions of the same character.

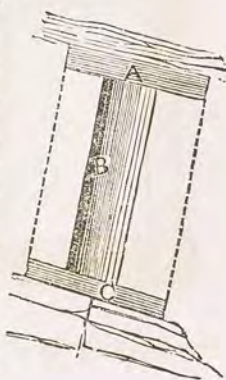
"The timber," says Mr. G. Thurean, M. E., "should be left as round as possible, and be well barked—the former for greater compactness and strength, the latter to prevent rot, which soon takes place in such workings, where the temperature changes, and consequently the air is moist and dry at intervals. The mode in which the various workings are being timbered should admit the repair and exchange of bad and rotten portions without interfering with any of the rest; this will effectually prevent the infection of sound pieces by the bad ones. For this purpose many means and remedies have been tried, out of which the constant watering is the most effectual in the end. This is done through the construction of little spouts in connection with the cisterns, which throw little streamlets of water over the timber, causing it to retain all the properties of well-seasoned and sound wood, without augmenting to any great extent the quantity of water to be lifted from the

deep levels of the mine. It is well and very desirable, that in the main drives and shafts of a well-conducted mine the same standard measure for timber should be adhered to. By doing so, greater facility for preparing a supply of timber on the "grass" is secured. The fitting is also less difficult, and the working may then be made of such uniform dimensions as will not cause any loss of time whilst being timbered."

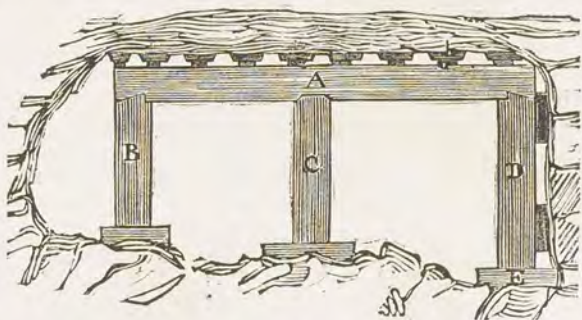
The amount and direction of the pressure in mines can be but very imperfectly estimated, and practical experience is the safest guide. The object of timbering is to meet and resist the pressure with sufficient force, and this must be done at right angles to it.



Underground timbers consist of three pieces, namely, The cap, (A,) the foot, (C,) and the prop, (B,) which may be seen in the accompanying cuts. The position and angle of pressure will be seen at a glance in the second engraving, where the timber stands on an inclined plane, from which the auriferous quartz or other ore has been excavated. The first cut gives the position of timbers in alluvial deposits, where there is only one pressure, namely, from above; the second shows how a prop is



placed to withstand two. In alluvial workings, the timbers are arranged as in the following sketch, which the reader will readily understand without further explanation. These workings are almost invariably on a level.



The next sectional engravings exhibit the usual structure of timbering in tunnels and drifts, or "drives," and in these the pressure is shown by arrows.



For the purpose of showing the general reader more

fully the manner of timbering tunnels in different descriptions of rock, we present two other drawings. The



tunnel to the left of the page is run through rock which is soft and liable to "cave" or crush inward.

In this it is necessary to have a foot-piece to brace the timbers apart and resist such pressure, besides having the sides and roof lined with planking. The other tunnel is supposed

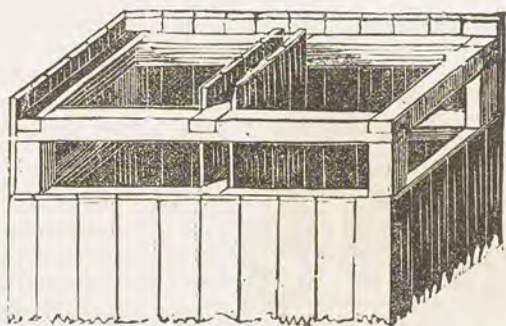
to run through ground which, on the one side, is firm

rock, and on the other yielding; so that it is necessary on the soft side to have a plank lining, whilst the rocky side is bare. Prospecting for a lode is often carried on by shafts instead of tunnels. In deep mines, too, it is necessary to have air shafts, which are worked from above or below, as the miner may elect, or both ways at the same time.

They are, however, mostly worked downward. In sinking shafts it is often necessary to timber them. Sometimes, where the main shaft is used for dirt-hoisting, it is double timbered; a dirt-tub being hoisted in one division of the shaft, its fellow is lowered down the other. We present a section of a double shaft, showing the timbering, etc. We earnestly recommend that none but thoroughly competent drifters be employed in our underground mines, as half the casualties that occur are occasioned by inexperience in timbering.



In the mines on the Comstock lode, in Nevada, the



width of the vein is so great, and it is composed in most places of such loose materials, that it becomes necessary to almost entirely fill the space from which the ore has been removed with a scaffolding of strong timbers, supported by braces in every direction. Fig. 16* represents a portion of the timbering of the Gould & Curry mine. As the width here varies from ten to forty feet, it is plain that it is of the utmost importance that the requisite strength should be obtained with the expenditure of the smallest possible quantity of timber, which is one of the heaviest items of expense in that region, as much of it has to be hauled for long distances over the mountain roads. The Gould & Curry, in 1864, paid \$160,488 for timber and lumber, and the Ophir Company, \$65,719.

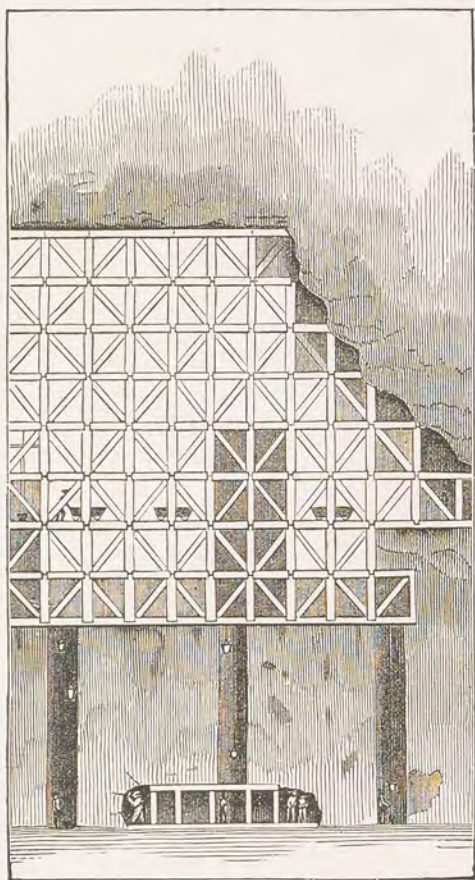


Fig. 16.*



MANUAL

OF

MINING AND METALLURGY.

THIS portion of our work is intended to furnish those who have not the advantage of a large library, with the substance of the researches of eminent miners and metallurgists, and to explain many processes and technical terms and phrases which are frequently not understood.

To form a portable book of reference for those who wish to acquire an additional knowledge of those arts—a repertory of every thing needful for the acquisition of a knowledge of the applications of geological science to purposes of utility.

To be a companion to the practical miner and metallurgist—an invaluable *vade mecum*. To enable the latter to extract, to assay, and to tell the properties of all the useful metals; and to acquaint the former with a knowledge of rocks and their order of superposition, by which great assistance in searching for the metals may be derived, and which will give him a clue to the rich depositories of mineral treasures.

An acquaintance with the general results, collected and classified by geology, must be our first guide in the investigation of mines. This enables the observer to judge whether any particular district should, from the nature and arrangement of its rocks, be susceptible of including within its bosom beds of workable and valuable ores. It indicates also, to a certain degree, what substances may probably be met with in a given series of

rocks, and what locality these substances will preferably effect. For want of a knowledge of these facts, many persons have gone blindly into researches equally absurd and ruinous; and an amount of money much greater than is generally known has thus been expended in vain. To attempt any thing without it, would be like sending a ship to sea without a helm to direct its course, without sails to catch the impelling breezes, and without a compass to guide its way. Formerly, indications of mines were taken from very unimportant circumstances; but geognostic observation has substituted more rational characters of metallic deposits. They may be called:

1. Negative indications, which are derived from that peculiar geological constitution which, from experience or general principles, excludes certain metallic matters; for example, granite, and, in general, every primitive formation, forbids the hope of ever finding within them combustible fossils, such as pit-coal, unless it be beds of anthracite; there, also, it would be vain to seek for common salt. Granite rocks very seldom include silver; or limestone, ores of tin. Volcanic territories never afford any metallic ores worth the working; nor do extensive veins usually run into secondary and alluvial formations. The richest ores of iron do not occur in secondary strata; and the ores of this metal, peculiar to these localities, do not exist among primary rocks.

2. Positive indications: as magnetic attraction, for iron ores; bituminous stone or inflammable gas, for pit-coal; the frequent occurrence of fragments of particular ores, etc.; or the geological epoch and nature of the rocks. Marks of this kind acquire new importance when, in a district susceptible of including deposits of workable ores, the vein-stones are met with which usually accompany any particular metal. The general aspect of mountains, whose flanks present gentle and continuous slopes, the frequency of sterile veins, the presence of metalliferous sands, the neighborhood of some known locality of an ore, as ironstone, in reference to coal; lastly, the existence of salt springs and mineral waters, may furnish indications.

Classification of Rocks.—To understand the relation which geology bears to mining, and the way in which it can be made subservient to its promotion, it is necessary to glance at some of the revelations which the science has made in regard to the structure and present condition of our globe, and the order in which the materials are arranged.

When a rock is divided into layers by seams, it is said to be stratified, or divided into strata; each of these layers is called a stratum. When one mass of rock is contained in another, it is said to be imbedded, or to occur in a bed. The inclination or general direction of the strata is called the dip. This is an important point to ascertain. Formation is used to signify a mass of mineral substances formed by the same agent, under the same circumstances, and at the same time.

Of the Instruments and Processes of Subterranean Operations.—It is by the aid of geometry, in the first place, that the miner studies the situation of the mineral deposits, on the surface and in the interior of the ground, determines the several relations of the veins and rocks, and becomes capable of directing the perforations toward a suitable end. The instruments are: 1. The magnetic compass, which is employed to measure the direction of a metallic ore, wherever the neighborhood of iron does not interfere with its functions. 2. The graduated semi-circle or clinometer, which serves to measure the inclination. 3. The cord or chain, for measuring the distance of one point from another. 4. When the neighborhood of iron renders the compass uncertain, a plane table or plate is employed.

Means of Penetrating into the Interior of the Earth.—1. Manual tools; 2. Gunpowder; and 3. Fire. The pick is a light tool used for digging or removing in small quantities. The side is used as a hammer; the point is of steel, carefully tempered. The gad is a punch or wedge of steel, with a wooden handle, driven into small openings of rocks. The shovel has a pointed form, to enable it to penetrate among the coarse and hard fragments of the mine rubbish. The blasting or shooting

tools are, a sledge, borer, claying-bar, needle or nail, scraper, tamping-bar. The borer is an iron bar, tipped with steel, formed like a thick chisel. A hole being bored, a cartridge is inclosed in it, furnished with a stem or tube, through which the powder may be ignited. Any soft species of rock, free from flinty particles, is used for cramming the hole, and is rammed by the tamping-bar. Each hole bored in a mine should be so placed, in reference to the schistose structure of the rock, and to its natural fissures, as to attack and blow up the least-resisting masses. The quantity of gunpowder should be merely sufficient to split it. In certain rocks and ores of extreme hardness, the action of fire is used with advantage, to diminish the cohesion of the rock.

When the existence of a deposit of ore is merely suspected, without positive proofs, recourse must be had to labors of research, in order to ascertain the richness, nature, and disposition of a supposed mine. Subterranean workings afford the most satisfactory knowledge. They are executed: 1. By longitudinal galleries, hollowed out of the mass of the beds or veins themselves, in following their course. 2. By transverse galleries, pushed at right angles to the direction of the veins. 3. By inclined shafts, which pursue the slope of the deposits, and are excavated in their mass. 4. By perpendicular pits. If a vein or bed unveils itself on the flank of a mountain, it may be explored, according to the greater or less slope of its inclination, either by a longitudinal gallery, opened in its mass from the outcropping surface, or by a transverse gallery falling upon it in a certain point, from which either a longitudinal gallery or a sloping shaft may be opened.

Metallic ores occur in four modes: 1. In regular interstratified layers or beds. 2. In veins or fissures crossing the strata, and filled with the ore, united with some matrix. 3. In irregular masses. 4. Disseminated in small fragments through the rocks.

METALS—THEIR CHEMISTRY AND GEOLOGY.

General Properties.—A metal is a body which conducts electricity and heat, which is opaque, and has a high and peculiar brilliancy, known as the metallic lustre.

Extraction.—Metals are often found naturally in their metallic form. When they so occur, they are said to be in a native state. Their characters are generally masked under some form of combination with oxygen or sulphur, and they are then said to be in the state of ore. They are met with, generally, in veins penetrating the strata, intermixed with various earthy substances. To separate the metal, after it is dug from the mine, the mass is broken up and subjected to the operation of sorting, stamping, washing, roasting, smelting, and refining.

Assaying.—This is the determination of the quantity of metal contained in any particular ore. The knowledge requisite for this is called the docimastic art.

GOLD.

1. GOLD. — *Geognostic Situation.*—This metal has hitherto been found only in the metallic state, either pure or in combination with other metals. It occurs in veins, and disseminated in primary and secondary rocks, and abundantly in alluvium or drift, which constitutes certain plains, and margins of rivers. The rocks in which it most often occurs are granite, quartz, slate, hornstone,

sandstone, limestone, gneiss, mica-slate, and especially in talcose slate, and rarely in graywacke and tertiary strata. It also occurs in veins of iron ore, antimony, zinc, lead, barytes, etc. When the metal exists in the bosom of primary rocks, it is particularly in schists. The gold which is found in alluvial deposits occurs in small particles or grains, called gold dust, mingled with sand and debris. It sometimes occurs in beds or layers, instead of veins, which conform to the regular structure of the slaty rocks. It is usually found alloyed with small portions of other metals, particularly silver and copper.

External Characters.—Color, golden or orange yellow, passing into grayish yellow; in some varieties, inclines to brass-yellow. Seldom occurs massive, often disseminated, capillary, amorphous dentritic, and crystallized in cubes, octohedrons, rhomboidal dodecahedrons, and tetrahedrons. Internally, shining, glistening, and metallic. Fracture, hackly. Tessular. No cleavage. Soft, malleable, ductile, tenacious. Specific gravity = 19.26 to 19.5.

Chemical Characters.—Unaltered by exposure to air, moisture, or acids. Soluble in *aqua regia*. Fusible with the blow-pipe. Melts at 2016° Fahrenheit.

Distinctive Characters.—Gold is the only metal which has a yellow color. Its malleability will distinguish it from iron and copper pyrites, and from yellow mica, for each of which it is often foolishly mistaken.

The gold of Africa is often adulterated with these pyrites and brass-filings. This fraud may easily be detected by throwing the dust into aquafortis, which dissolves the substances and leaves the gold untouched.

PLATINUM.

2. PLATINUM.—*Geognostic Situation.*—This metal occurs only in the metallic state, associated or combined with various metals, as iridium, rhodium, palladium, osmium, copper, iron, lead, gold, silver. It is frequently disseminated in rocks of igneous origin, as the primary.

It is often found in sienite, associated with gold. But it occurs principally in alluvium or drift.

External Characters.—Color, very light steel-gray, approaching to silver-white. Occurs in grains and rolled pieces, seldom larger than a pea, and resembling coarse iron filings. Roundish. Shining and glistening. Streak unchanged. Hardness nearly equal to that of iron. Malleable; ductile. Structure sometimes lamellar, but often not obvious. Specific gravity=20.98.

Chemical Characters.—Infusible in the hottest furnaces, but melts before the compound blow-pipe. Unaltered by exposure to air, moisture, or acids. Dissolves in aqua regia.

SILVER.

3. SILVER.—*Geognostic Situation.*—This metal is found mostly in primary and secondary slates. It is found native, also as ore combined with sulphur, chlorine, copper, antimony, lead, arsenic, gold. The rocks, richest in it are gneiss, mica-slate, clay-slate, graywacke.

Native Silver.

Geognostic Situation.—Primitive and secondary rocks with the ores of silver, copper, cobalt, etc. It often occurs penetrating crystals, or amorphous pieces of common quartz.

External Characters.—Color, silver-white, often tarnished gray, or reddish. Occurs dentiform, capillary, ramose, reticulated, seldom massive, more frequently disseminated; also in plates and spangles, and crystallized in tubes, octohedrons, rhomboidal docahedrons and tetrahedrons. Lustre, splendent to glimmering. Fracture, fine, hackly. Specific gravity=10 to 10.5.

Chemical Characters.—Fusible into a globule. Melts at 1873°, or a red heat. Soluble in aquafortis, forming the well-known lunar caustic.

Distinctive Characters.—Its color and malleability.

Composition.—Silver, with a little iron, antimony, copper, or arsenic.

Antimonial Silver. (Dicrasite.)

Geognostic Situation.—In primary rocks, as granite and clay-slate, associated with the other ores of silver.

External Characters.—Color, silver or tin-white. Occurs massive, in grains, and in cylinders, also in curved laminae. Yields to the knife. Fracture, uneven. Specific gravity = 9 to 10.

Chemical Characters.—Fusible, with the emission of antimonial vapor, into a globule of silver.

Distinctive Characters.—Want of ductility, and the antimonial vapor; not giving a blue globule with borax.

Composition.—Silver, 73; antimony, 27.

Sulphuret of Silver. (Silver Glance.)

Geognostic Situation.—Primary and secondary rocks, associated with the other ores of silver. It is an important ore for the extraction of the noble metal.

External Characters.—Color, dark, lead-gray, often with an iridescent tarnish. Occurs in tubes and octohedrons; also reticulated, ramose, lamelliform, amorphous, and in plates. Cleavage, imperfect. Fracture, flat, conchoidal. Malleable. Easily sectile. Specific gravity=7.

Chemical Characters.—Fusible with intumescence and odor of sulphur, leaving a globule of silver.

Distinctive Characters.—It may be distinguished from native silver by its less specific gravity, and its sulphurous odor under the blow-pipe.

Composition.—Silver, 85; sulphur, 15.

Brittle Sulphuret of Silver. (Stephanite.)

Geognostic Situation.—Primary rock, with the other ores of silver.

External Characters.—Color, dark, lead-gray, or bluish-gray, passing into iron-black. Occurs massive and disseminated; also in hexahedral prisms. Lustre, metallic or dull. Structure, foliated; crystals mostly intercept

each other. Soft and brittle. Fracture, conchoidal. Specific gravity=7.

Chemical Characters.—Fusible, with the evaporation of sulphur, arsenic, and antimony, into a globule of silver surrounded by a slag. Soluble in aquafortis.

Distinctive Characters.—It differs from sulphuret of silver in its want of malleability, and from other ores by its dark color and brittleness.

Composition.—Silver, 66.5; antimony, 10; iron, 5; sulphur, 12; arsenic 5.

Sulphureted Antimonial Silver. (Pyrargiryse.)

Geognostic Situation.—Primary rocks, chiefly in granite, mica-slate, and porphyry. It is a valuable ore.

External Characters.—Color, red of various shades, passing into lead-gray and grayish black; powder, crimson red. Occurs in masses and grains, also dentritic, membranous, capillary, and crystallized in hexahedral prisms, terminated by scalenohedrons; also in double six-sided pyramids. Lustre, metallic adamantine; crystals often striated. Structure, imperfectly foliated. Yields to the knife. Opaque. Specific gravity=5.20 to 6.68. Hardness, 2–2.5.

Chemical Characters.—Fusible, with antimonial fumes.

Distinctive Characters.—It differs from sulphuret of arsenic in having a greater specific gravity, and in leaving a globule of silver. Sulphuret of mercury is entirely dissipated by the blow-pipe. The sulphuret of silver is malleable. Specular oxyd of iron is magnetic after being submitted to the blow-pipe, and the red oxyd of copper is readily reduced to the metallic state by the blowpipe.

Composition.—Silver, 60; antimony, 23.5; sulphur, 17.5.

Muriate of Silver. (Horn Silver.)

Geognostic Situation.—Primary rocks, with the other ores. It is a good ore for the extraction of the precious metal.

External Characters.—Color, pearl-gray, greenish or

yellowish or greenish white and brown. Occurs massive, investing other minerals, reniform, amorphous, and crystallized in tubes, octohedrons, and acicular prisms. Lustre, glistening and wavy. Soft, yields to the knife and to pressure. Malleable. Feebly translucent. Becomes brown by exposure. Specific gravity = 5.5.

Chemical Characters.—Fusible in the flame of a candle. Before the blowpipe, emits muriatic acid fumes. Rubbed on moistened zinc, it leaves a film of silver.

Distinctive Characters.—Muriate of mercury is entirely volatile before the blowpipe, and does not leave a silver globule.

Composition.—Chlorine, 29.7; silver, 75.3.

MERCURY.

4. MERCURY.—This metal is sometimes found in the native state, but the ore or source whence the greater portion is obtained is the

Sulphuret of Mercury. (Cinnabar.)

Geognostic Situation.—Occurs chiefly in new red sandstone; sometimes in a sort of mica-slate, limestone, gneiss, graywacke, beds of bituminous shale, associated with black mineral resin, gray sandstone and limestone, clay, alluvium, and in rocks of the coal formation.

External Characters.—Color, scarlet or carmine, passing into cochineal red and lead-gray; sometimes with a tinge of yellow. Occurs massive, and crystallized in acute rhomboids; some varieties have a fibrous structure. Translucent or opaque. Streak, scarlet red. Lustre, adamantine, inclining to metallic; sometimes shining silky. Fracture, granular or fibrous. Sometimes occurs in thin plates or tabular crystals. Specific gravity = 8.

Chemical Characters.—Volatile before the blowpipe, with the odor of sulphur.

Distinctive Characters.—From sulphuret of arsenic,

red silver ore, arseniate of cobalt, and red oxyd of copper, it is distinguished by its chemical character.

Composition.—Mercury, 84.5; sulphur, 14.75.

COPPER.

5. COPPER.—*Geognostic Situation*.—Occurs in beds, imbedded in various primary rocks, and as high in the secondary series as the new red sandstone; also in large blocks in alluvial districts; very rarely in tertiary rocks.

The ores of copper present the following varieties:

Native Copper.

Geognostic Situation.—In the veins of primary and secondary rocks.

External Characters.—Color, copper-red, tarnished externally, brownish black. Occurs dendritic, capillary, reniform, and amorphous; also crystallized in cubes and octohedrons. Malleable. Specific gravity=8.5.

Chemical Characters.—Fusible. Soluble in acids.

Composition.—Nearly pure copper.

Sulphuret of Copper.

Geognostic Situation.—Found in almost every kind of repository in all the great classes of rocks, particularly in beds and veins in primary and secondary rocks. It is a valuable ore.

External Characters.—Color, blackish steel-gray, sometimes iridescent; internally, lead-gray. Occurs massive, and in pseudomorphous crystals; also crystallized in long tabular, six-sided prisms, and in double six-sided pyramids. Structure, lamellar. Tessular. Cleavage easy, with brilliant faces. Easily broken into grains. Fracture conchoidal. Specific gravity=5.

Chemical Characters.—Soluble in hot aquafortis. Fusible.

Distinctive Characters.—Gray copper decrepitates under the blowpipe, and is harder. This gives out only the fumes of sulphur.

Composition.—Copper, 76.50; sulphur, 22; iron, 0.50.

Copper Pyrites.

Geognostic Situation.—Same as that of the preceding. It is one of the most abundant and valuable ores of copper.

External Characters.—Color, brass-yellow. Occurs dendritic, stalactical, amorphous, in concretions, and crystallized in tetrahedrons and dodecahedrons. Lustre, metallic. Structure, lamellar. Crystals, small, and seldom perfect. Cleavage, tessular. Yields to the knife. Fracture, commonly uneven. Specific gravity=4.3.

Chemical Characters.—Fusible. Tinges borax green.

Distinctive Characters.—Iron pyrites does not tinge borax green. Native bismuth is lamellated, and native gold is malleable.

Composition.—Copper, 40 to 35.3; iron, 40 to 33; sulphur, 20 to 35.

Gray Copper.

Geognostic Situation.—Accompanies the other ores of copper.

External Characters.—Color, steel-gray, passing into black. Streak, brownish. Occurs amorphous, disseminated, and crystallized in tetrahedrons. Lustre, metallic; brittle. Crystals, small. Specific gravity=5.

Chemical Characters.—Fusible, but not easily reduced.

Distinctive Characters.—Specular oxyd of iron is magnetic; arsenical iron is harder, and gives out the fumes of arsenic when heated.

Composition.—Copper, 52; iron, 23; sulphur, 14.

Red Oxyd of Copper.

Geognostic Situation.—Associated with the other copper ores.

External Characters.—Color, red. Occurs amorphous and crystallized in octohedrons and cubes. Structure, lamellar. Lustre, metallic, adamantine. Fracture, conchoidal and uneven. Translucent. Yields to the knife. Brittle. Specific gravity=4 to 5.9.

Chemical Characters.—Fusible and easily reduced. Dissolves in aquafortis with effervescence; in muriatic acid, without.

Distinctive Characters.—Its chemical characters.

Composition.—Copper, from 88.5 to 91; oxygen, from 11.5 to 9.

Blue Carbonate of Copper.

Geognostic Situation.—In primary and secondary mountains.

External Characters.—Color, blue. Occurs massive, stalactical, incrusting, disseminated, and crystallized. Fracture imperfectly foliated, usually presenting broad fibres.

Chemical Characters.—Infusible without a flux; with borax gives a green glass. Dissolves in aquafortis with effervescence.

Distinctive Characters.—Insoluble in water; does not become magnetic under the blowpipe.

Composition.—Oxyd of copper, 70; carbonic acid, 24; water, 6.

Tests for Copper.—To a solution of this metal present a plate of iron, result = metallic copper; potash, result = green precipitate; ammonia, (hartshorn,) result = blue color.

Copper melts at 1996° ; it is ductile, malleable, and tenacious; it is hard, elastic, and sonorous.

IRON.

6. IRON.—*Geognostic Situation.*—It occurs in primary and secondary rocks.

The ores from which the iron of commerce is extracted are:

Brown Hematite.

Geognostic Situation.—Occurs abundantly in primary districts, and sometimes in secondary. It yields the finest kind of iron.

External Characters.—Color, brown, yellowish, or blackish brown; on the outside resembling black glazed

earthenware. Occurs stalactical, tuberous, nodular, and amorphous. Structure, fibrous. Lustre, silky and resinous; yields to the knife. In a variety of this ore the structure is compact; lustre, none; streak, yellowish brown; fracture, conchoidal or earthy.

Red Hematite.

Geognostic Situation.—Chiefly in the primary, often in lead mines. It yields the best of iron for drawing and rolling.

External Characters.—Colors, blood-red and dark steel-gray. Occurs massive, and in plates; also reniform, globular, and pulverulent. Fracture, uneven and earthy. Yields easily to the knife. Adheres to the tongue. Specific gravity, 4.75.

Chemical Characters.—Infusible, but becomes magnetic.

Composition.—Oxyd of iron, 90; silix, 2; lime, 1; water, 3.

Specular Oxyd of Iron. (Iron Glance.)

Geognostic Situation.—Occurs chiefly in primary mountains, associated with magnetic iron, red hematite, quartz, etc.; also in secondary rocks. Affords good malleable iron.

External Characters.—Color, steel-gray, with a highly polished surface; often tarnished. Streak, cherry-red. Occurs crystallized in pyramidal dodecahedrons, hexahedral tables; also massive, disseminated, in concretions. Structure, lamellar. Lustre, brilliant; slightly attracted by the magnet. Specific gravity = 5.52.

Chemical Characters.—Infusible. Insoluble in acids.

Distinctive Characters.—Yields a red powder when heated, and becomes magnetic.

Composition.—Iron, 69; oxygen, 31.

Magnetic Oxyd of Iron. (Iron Sand.)

Geognostic Situation.—Occurs imbedded in trap rocks, and called mountain ore. Furnishes best bar iron, and yields from fifty to ninety per cent of the metal.

External Characters.—Color, iron-black. Occurs in minute grains; also in octahedral crystals. Fracture, conchoidal. Strongly magnetic. Powder, black.

Chemical Characters.—Infusible by blowpipe.

Composition.—Oxyd of iron, 85.50; oxyd of titanium, 14; oxyd of manganese, 0.50.

Spathic Iron. (Clay Iron Ore.)

Geognostic Situation.—It occurs in veins in granite, gneiss, mica-slate, clay-slate, and graywacke, and in these it is associated with ores of lead, cobalt, silver, but seldom with nickel and bismuth; more frequently with galena, copper ore, iron pyrites, and antimony ore. In other veins it is accompanied with brown, red, and black iron ore, calcareous spar, and quartz. But the most extensive formations of this ore are in carboniferous limestone, in which it is arranged in thick beds. It is also found filling up amygdaloidal cavities in trap rocks. It is excellently suited for steel-making; the black variety affording the best.

External Characters.—Colors, yellow, white, brown, and black. Occurs massive, disseminated, with pyramidal impressions; also in granular distinct concretions—nodular; and crystallized. Structure foliated or lamellar. Lustre, shining vitreous. Streak, white, or yellowish brown. Yields to the knife; easily broken. Crystals usually small, and found in groups. Specific gravity = about 4.

Chemical Characters.—Infusible, blackens, and becomes magnetic. Effervesces with muriatic acid. Heated with borax, it makes an olive-green glass.

Distinctive Characters.—From the earthy minerals it is distinguished by its weight. From other iron ores, by crystalline, foliated cleavage; and from blende, by its yielding magnetic iron.

Composition.—Oxyd of iron, 58; carbonic acid, 35; oxyd of manganese, 4.25; magnesia, 0.75; lime, 0.5.

Tests for Iron.—Infusion of galls, when added to iron dissolved in an acid, gives a black precipitate, (black

ink;) prussiate of potash gives a blue precipitate, (blue ink.)

LEAD.

7. LEAD.—The ore which is generally wrought, and from which nearly all the lead of commerce is procured, is the

Sulphuret of Lead. (Galena.)

Geognostic Situation.—Occurs in veins, beds, and imbedded masses, in primary and secondary mountains, but most frequently in the latter, and particularly in limestone. It is commonly associated with the ores of zinc, copper, and iron, and often with those of silver. When it is found in the primary rocks, it is generally in granite. It is also found in alluvial deposits.

External Characters.—Colors, bluish-gray, lead-gray, and on the outside, blackish-gray. Occurs amorphous, reticulated, and crystallized in cubes and octohedrons. Structure, lamellated. Lustre, metallic. Perfectly sectile; soft. Very brittle. Opaque.

Chemical Characters.—When heated, first decrepitates, then emits the smell of sulphur, melting into a globule of lead.

Distinctive Characters.—Blende, molybdena, and graphite are infusible.

Composition.—Lead, sulphur, lime, and silice.

Tests for Lead.—Glauber's salts, and an infusion of galls, give to a solution of this metal a white precipitate.

TIN.

8. TIN.—The only ore that is wrought to obtain this metal, is the

Oxyd of Tin. (Tinstone.)

Geognostic Situation.—Occurs most commonly in primary rocks, where it is found in veins, traversing granite, gneiss, mica-slate, clay-slate, and porphyry, and is usually associated with chlorite, iron pyrites, topaz, quartz, fluor, etc. The metal extracted from the ore taken from this

situation is called block tin. It is also found in alluvium and drift, and the ore is called stream tin, from which the metal being extracted, it becomes the grain tin of commerce.

External Characters.—Colors, brown, black, green, white, red, and yellow. Occurs in crystals, and in masses, from the size of grains to that of the fist. Lustre, resinous or adamantine. Streak, grayish-white. Structure, lamellar. Gives sparks with steel. Brittle. Specific gravity = from 6.7 to 7.

Chemical Characters.—Decrepitates, but in powder may be reduced to metallic state on charcoal.

Distinctive Characters.—Spathic iron leaves a globule of iron under the blowpipe. Blende is infusible, and not so hard.

Composition.—Tin, 77.5 ; oxygen, 21.5 ; oxyd of iron, 0.25 ; silic, 0.75.

Test for Tin.—To a solution holding the metal present a plate of iron, result = metallic tin.

ZINC.

9. ZINC.—*Geognostic Situation.*—Primary and secondary rocks.

Blende. (*Mock Lead, False Galena, Black Jack.*)

Geognostic Situation.—Occurs in veins in primary and secondary rocks, generally associated with galena, with iron and copper. This ore is commonly too widely disseminated in its gangue to make it profitable. It is, however, used after roasting in the preparation of brass.

External Characters.—Colors, yellow, brown, and black. Occurs massive, lamelliform, disseminated, in granular concretions, and crystallized. Lustre, shining and adamantine. Yields to the knife. Brittle. Structure, foliated. Specific gravity = 3.7 to 4.

Chemical Characters.—When heated, decrepitates. When thrown into oil of vitriol, it gives the smell of rotten eggs.

Distinctive Characters.—Infusible. Does not tinge borax green.

Composition.—Zinc, sulphur, iron, and silic.

Calamine.

Geognostic Situation.—Occurs in beds, nests, filling up or lining hollows, in secondary limestone and conglomerate rock; also in veins, usually along with oxyd of iron, and sometimes with galena.

External Characters.—Colors, gray, greenish, or brown-yellowish, and sometimes nearly white. Occurs crystallized, compact, amorphous, pseudo-morphous, and cupriferous. Yields to the knife. Specific gravity = 3.35 to 4.41.

Chemical Characters.—Infusible. Dissolves with effervescence in muriatic acid or warm aquafortis.

Composition.—Oxyd of zinc and carbonic acid.

Red Ore of Zinc.

Geological Situation.—Iron mines; also in limestone.

External Characters.—Color, red. Occurs massive and disseminated. Lustre, shining, by exposure becomes dull. Structure, foliated. Yields to the knife. Brittle. Specific gravity = 6.22.

Chemical Characters.—Infusible. Soluble with effervescence in acids.

Distinctive Characters.—Infusibility and weight.

Composition.—Oxyd of manganese and oxyd of zinc.

M A N G A N E S E .

10. MANGANESE.—This metal, in its metallic state, has not been converted into any use; but the ore, which answers, without preparation, all the purposes for which the metal is employed, is the

Black Oxyd of Manganese.

Geognostic Situation.—Occurs in veins and imbedded masses in primary rocks; frequently found with the ores of iron.

External Characters.—Color, very dark steel gray. Occurs massive, in fibrous concretions, and crystallized. Lustre, metallic. Streak, black. Fracture, conchoidal and earthy.

Chemical Characters.—Infusible alone; but with borax forms a purple globule.

Composition.—Manganese, oxygen, and water.

COBALT.

11. COBALT.—Cobalt is not procured in its metallic state for the purposes of art. The preparations of it in general use are zaffre and smalt. The ore from which they are obtained is

Arsenical Cobalt.

Geognostic Situation.—Occurs in veins, traversing primary rocks, associated with nickel, bismuth, silver, arsenic, and copper.

External Characters.—Color, silver-white, with a tinge of copper-red. Occurs massive, dendritic, reticulated, stalactical, and crystallized in cubes and octahedrons. Lustre, metallic. Brittle. Fracture, conchoidal. Yields with difficulty to the knife. Specific gravity = 6.33 to 7.30.

Chemical Characters.—In the flame of a candle it emits the garlic odor and turns black. Melted with borax, gives a blue glass.

Composition.—Cobalt, arsenic, and sulphur.

To Prepare Zaffre.—Break the ore, with hammers, into pieces about the size of a hen's egg. Pound the mineral in stamping-mills and sift. Wash, and then put into a large, flat-bottomed, arched furnace, where the flame of the wood is made to play upon it. Stir often. The vapor is conveyed through a long flue, in which it is condensed. When the fumes cease, the ore is removed and reduced to powder, and again exposed to heat. It is then reduced to powder and sifted. This is the oxyd of cobalt. It is, however, commonly adulterated with three times its weight of powdered flints, moistened with water.

To Prepare Smalt.—Mix the pure zaffre with equal parts of potashes and sand. Heat it in large pots for ten or twelve hours, and frequently stir. Take it out in ladles and drop into water, then pound, sift, and grind.

NICKEL.

12. **NICKEL.**—The ore from which this metal is obtained is

Arsenical Nickel. (*Kupfer, or Copper Nickel.*)

Geognostic Situation.—Accompanies cobalt. Secondary rocks.

External Characters.—Color, copper-red. Tarnishes. Occurs massive, reticulated, and botryoidal. Lustre, metallic. Yields with difficulty to the knife. Specific gravity=6.60 to 7.70.

Chemical Characters.—Gives out garlic odor when heated. Forms a green solution in aquafortis.

Composition.—Nickel, arsenic, iron, lead, sulphur, and cobalt.

BISMUTH.

13. **BISMUTH.**—*Geognostic Situation.*—Primary rocks, and particularly in quartz, gneiss, and mica-slate, generally associated with cobalt, arsenic, silver, iron pyrites, and galena. When found native and alone, the metal is fit for use immediately.

External Characters.—Color, silver-white, inclining to red. Occurs amorphous, plumose, reticulated, and crystallized. Structure, lamellar. Lustre, metallic. Softer than copper. Tarnishes. Melts at 476°. Specific gravity=9.

ARSENIC.

14. **ARSENIC.**—Arsenic is not used in the metallic state in the arts, and no mines are wrought for obtaining it. The forms in which it is employed are :

Oxyd of Arsenic. (*White Arsenic.*)

Geognostic Situation.—This is a very rare mineral. It is found chiefly in the primary rocks, with the ores of cobalt, copper, lead, silver, etc.

External Characters.—Color, white. Occurs earthy, capillary, and investing ; also crystallized. Lustre, vitre-

ous. Fracture, conchoidal. Brittle. Specific gravity=3.7.

Chemical Characters.—At 380° it sublimes. Heated with charcoal, it gives a garlic odor. Soluble in ten parts of hot water. Poison.

Realgar.

Geognostic Situation.—Occurs most frequently in veins in the primary rocks, less often in secondary; also among volcanic matter.

It may be formed artificially, by heating white arsenic (ratsbane) with half its weight of sulphur, until the mixture is brought into a state of perfect fusion.

External Characters.—Color, ruby-red. Occurs amorphous, disseminated, in flakes, in concretions, and crystallized. Lustre, resinous. Streak, orange-yellow. Translucent. Soft; brittle. Becomes electric when rubbed on the sleeve. Specific gravity=3.3 to 3.4.

Chemical Characters.—Melts easily, and burns with a blue flame and white smoke, emitting the smell of garlic and sulphur.

Distinctive Characters.—The chromate of lead is much heavier, and tinges borax green. The red ores of silver and mercury are heavier, and give a red streak.

Composition.—Arsenic, 69; sulphur, 31.

Orpiment.

Geognostic Situation.—Secondary and primary rocks.

It may be prepared artificially, by fusing together equal parts of white arsenic and sulphur.

External Characters.—Color, lemon-yellow. Occurs reniform, disseminated, and in plates. Lustre, shining. Flexible. Translucent. Sectile. Specific gravity=3.4 to 3.6.

Chemical Characters.—Burns, emitting the smell of arsenic and sulphur. Becomes electric by friction.

Composition.—Arsenic, 57; sulphur, 43.

ANTIMONY.

15. ANTIMONY.—The ore from which the antimony of commerce is obtained is the

Sulphuret of Antimony.

Geognostic Situation.—Primary and secondary rocks, chiefly in granite, gneiss, and mica-slate, associated with galena, blende, the ores of iron, copper, and arsenic.

External Characters of the Ore.—Color, lead-gray. Streak, unchanged. Occurs massive, composed of delicate threads or needles, and crystallized. Lustre, splendid. Fracture, fibrous. Yields to the knife; brittle. Specific gravity=4 to 4.80.

Chemical Characters.—Melts in a candle-flame. Before the blowpipe, emits the smell of sulphur, and sublimes.

Composition.—Antimony, 74; Sulphur, 26.

Anthracite. (Blind or Glance Coal.)

Geognostic Situation.—Occurs in imbedded masses, beds and veins, in primary and secondary rocks, often in graywacke, sandstone, trap-rocks, slate, etc. It is also called stone-coal.

Black or Bituminous Coal.

Geognostic Situation.—Chiefly in the secondary series, sometimes in clay, sandstone, and limestone. Its varieties are called slate, foliated, cannel, and coarse coal.

Lignite. (Brown Coal.)

Geognostic Situation.—Chiefly occurs in secondary rocks; also in alluvium. Its other names are, bituminous wood, earthy coal, alum earth, jet and moor coal.

Rock Salt.

Geognostic Situation.—Secondary strata; often found associated with gypsum, clay, marl, etc.

Limestone.

Geognostic Situation.—Almost every rock below drift. The best marble occurs in the upper part of the primary, and lower part of the secondary rocks.

Gypsum.

Geognostic Situation.—New red sandstone, and other secondary rocks.

Clay.

Geognostic Situation.—Secondary rocks. Porcelain clay is found in connection with granite.

Plumbago.

Geognostic Situation.—In the coal formation; also in clay-slate. It is often called graphite or black-lead.

Precious Stones.

Geognostic Situation.—Nearly all of them, as the sapphire, emerald, spinel, chrysoberyl, chrysoprase, topaz, iolite, garnet, tourmaline, chalcedony, amethyst, etc., are always in the primary rocks. Quartz, in the form of rock-crystal, carnelian, cat's paw, sardonyx, jasper, etc., is found often in secondary strata, especially in the trap-rocks. The diamond is generally found in drift.

STANDARD OF GOLD.

Gold is seldom found in nature in a pure state, and for the purposes of the arts, is alloyed with a small quantity of either silver or copper, by which its hardness, as well as its fusibility, are considerably increased.

In this country the standard of the alloys of gold is calculated in fractions of unity expressed in carats. Unity is supposed to be divided into twenty-four carats, whilst the carat itself is subdivided into thirty-two thirty-secondths; so that unity may be considered as made up of seven hundred and sixty-eight thirty-secondths of a carat. In this way the gold coinage of the United Kingdom is said to have a standard of twenty-two carats; or, in other words, a sovereign consists of an alloy, in which, in every twenty-four parts, there are twenty-two parts of fine gold, and two parts of alloy. It is for this reason that for the assay of bullion, twelve grains of the substance are conveniently operated on, since every half grain of fine gold found by experiment will evidently correspond to one carat in the composition of the alloy.

The various subdivisions of the carat are represented by fractions of a grain, and the true standard is thus strictly and readily determined.

TABLE SHOWING THE QUANTITY OF GOLD TO THE TON OF ORE CORRESPONDING TO THE WEIGHTS IN GRAINS OBTAINED FROM FOUR HUNDRED GRAINS OF MINERAL.

If 400 grains of Ore give Fine Gold.				One Ton of Ore will yield.				If 400 grains of Ore give Fine Gold.				One Ton of Ore will yield.			
rs.	oz.	dwt.	grs.					grs.	oz.	dwt.	grs.				
.001	0	1	15					.200	16	6	16				
.002	0	3	6					.300	24	10	0				
.003	0	4	21					.400	32	13	8				
.004	0	6	12					.500	40	16	16				
.005	0	8	4					.600	49	0	0				
.006	0	9	19					.700	57	3	8				
.007	0	11	10					.800	65	6	16				
.008	0	13	1					.900	73	10	0				
.009	0	14	16					1.000	81	13	8				
.010	0	16	8					2.000	163	6	16				
.020	1	12	16					3.000	245	0	0				
.030	2	9	0					4.000	326	13	8				
.040	3	5	8					5.000	408	6	16				
.050	4	1	16					6.000	490	0	0				
.060	4	18	0					7.000	570	13	8				
.070	5	14	8					8.000	653	6	16				
.080	6	10	16					9.000	735	0	0				
.090	7	7	0					10.000	816	13	8				
.100	8	3	8					20.000	1633	6	16				

Specific Gravity.—The specific gravity of gold having been mentioned in the former part of this book as a means of distinguishing that metal from other substances of near the same color, it is necessary that the meaning of the term specific gravity should now be explained, as also the methods by which the specific gravities of bodies may be conveniently ascertained.

By the specific gravity or *density* of a substance is

understood its weight as compared with that of an equal bulk of some other body taken as a standard of calculation. In the case of solids and liquids, distilled water, at the temperature of sixty degrees Fahr., is taken as this point of comparison; but the densities of the gases are usually estimated in relation with common air taken as unity.

In order to determine the specific gravity of a body, it is necessary to ascertain its weight when weighed in air, and also to learn how much it loses in weight by immersion in water. If we call its weight in air W , and its weight when suspended in water w , it is evident that $W - w$ will represent the weight of an equal volume of that liquid, as whenever a solid is placed in a liquid that covers the top of it, it must necessarily displace precisely its own bulk of the medium in which it is situated. The specific gravity of a body being, then, its weight in comparison with an equal bulk of some other substance taken as unity, it will readily be obtained from the above data, and is nothing more than the relation existing between W and $W - w$, which will consequently be represented by $\frac{W}{W - w}$.

The most common method of taking specific gravities, when large pieces of the substance to be operated on can be readily procured, is by means of what is called the hydrostatic balance (Fig. 17,) of which the pans are



Fig. 17.

suspended by strings of unequal length. In order to obtain a density by this instrument, the substance to be operated on should be suspended by a hair or filament of silk to the shorter pan, which has a hook attached to its under side for that purpose. Weights should not be added in the other pan until the equilibrium is restored; and when this takes place the weight W will be noted as that of the substance in air. To obtain the corresponding weight of an equal bulk of water at the tem-

perature of sixty degrees Fahr., a vessel of that liquid is now placed under the shorter pan in such a way that the suspended fragment of which we desire to know the density may be completely immersed in it, and weights are to be removed from the other pan until the equilibrium be again restored. The second weight thus obtained w , deducted from W , ascertained by weighing the substance in air, gives the weight $W-w$ of an equal

volume of water, and the required specific gravity $\frac{W}{W-w}$

is at once obtained by dividing the weight in air by this difference. When it is required to conduct these operations with great accuracy, it is necessary to employ a very delicate balance, and to remove any air-bubbles that may attach themselves to the substance when placed in water, by means of a camel's hair-brush. The temperature of the water in such cases should also be constantly kept at sixty degrees, and any deviation of the barometer from thirty inches should be duly allowed for. In cases where but small fragments of a substance can be obtained, the instrument called the specific-gravity bottle may be employed. This is nothing more than a common bottle, of which the stopper, nicely fitted by grinding, is traversed by a capillary tube, and so arranged that it can not sink beyond a line marked upon the neck of the vial. By this means it is easy to obtain a constant weight of water in the instrument, since, if it be filled beyond the line and the stopper afterward be forced into it, the residual liquid will escape through the capillary tube, and the bottle remain exactly full. In order to take a specific gravity by the aid of this vial, it should first be weighed when full of water; a counterpoise equivalent to the weight of the bottle being placed in the opposite scale-pan. The substance to be examined must then be weighed in air, and afterwards dropped into the vial, care being taken to avoid the loss of the most minute particle. The stopper is now replaced, so that the bottle may again remain exactly full, and the whole is reweighed. The difference between the weight of the bottle of water, W , added to

the weight of the substance in air, W' or $W + W'$; and that of the weight of the bottle of water, w , when containing the fragment to be examined, is evidently $W + W' - w$, and the specific gravity sought, will, consequently, be expressed by $\frac{W + W'}{W + W' - w}$.

The following example may probably render the above explanations more readily understood. We find that the bottle, filled with distilled water, weighs 995.74 grains = W .

Another substance which is supposed to be gold-dust, weighs in air 105.30 grains = W' . The bottle with the supposed gold-dust and water together, weighs 1095.52 = w . The united weights of the substance and bottle of water together being 1101.04 grains = $W + W'$, the weight of the equivalent volume of water displaced will be $1101.04 - 1095.52 = 5.52 = W + W' - w$. It consequently follows that the specific gravity of the substance is—

$$\frac{105.30}{5.52} = 19.07 = \frac{W + W'}{W + W' - w}.$$

The above result shows, then, that the substance examined was really gold-dust, and but little mixed with any kind of alloy.

Instead of operating as above described, the density of any finely-divided body, such as gold-dust, may be readily and accurately determined by the following process:

The substance is first weighed in air, and then placed in a specific gravity-bottle of known capacity, and the bottle carefully filled from a graduated pour-ette, up to the point marked on its neck. On consulting the pour-ette, every division of which may represent one grain of distilled water, it is at once seen how many grains of water have been required to fill the bottle, when containing the known weight of gold, up to the mark on its neck. On deducting this from the ascertained capacity of the bottle, the weight of the displaced water is at once seen. The weight of the substance in air is now to

be divided by this result, and the specific gravity of the body examined is at once obtained.

The advantage of this method under circumstances in which distilled water cannot be obtained is very obvious, as not only will any liquid not acting on the substance under examination answer for the experiment, but the results found are also perfectly independent of both temperature and pressure.

From the known specific gravity of gold, as well as that of the quartz rock with which it is commonly associated, it becomes easy, after determining the density of the mixture, to ascertain by calculation the relative amount of each present in any particular specimen.

To find the Proportions of Gold in a Mixture of Gold and Quartz.

The specific gravity of the gold = 19.000

The specific gravity of the quartz = 2.600

These numbers can be corrected when experiment shows the specific gravities to be different.

A. Ascertain the specific gravity of the mixture of gold and quartz. Suppose it to be 8.067.

B. Deduct the specific gravity of the mixture from the specific gravity of the gold; the difference is the ratio of the quartz by volume:

$$19.000 - 8.067 = 10.933$$

C. Deduct the specific gravity of the quartz from the specific gravity of the mixture; the difference is the ratio of the gold by volume:

$$8.067 - 2.600 = 5.467.$$

D. Add these ratios together, and proceed by the rule of proportion. The product is the percentage of gold by bulk.

$$10.933 + 5.467 = 16.400.$$

$$16.4 \text{ is to } 5.467 \text{ as } 100 \text{ is to } 33.35.$$

E. Multiply the percentage of gold by bulk, by its specific gravity. The product is the ratio of the gold in the mixture by weight:

$$33.35 \times 19.00 = 633.65.$$

F. Multiply the percentage of quartz by bulk, by its specific gravity. The product is the ratio of the quartz in the mixture by weight:

$$66.65 \times 2.60 = 173.29.$$

G. To find the percentage add these ratios together, and proceed by the rule of proportion:

$$633.65 + 173.29 = 806.94.$$

806.94 is to 633.65 as 100 is to 78.53.

Hence a mixture of quartz and gold, having the specific gravity of 8.067, contains 78.53 per cent of gold by weight.

THE MINES OF CALIFORNIA, OREGON, NEVADA, BRITISH COLUMBIA, ETC.

As this work is more particularly intended for those persons living in the above States and territories, it becomes necessary to give our attention for a short time to what are popularly termed "the mines of the Pacific coast." So much has been said and written on the subject of the discovery of the gold mines of California, that we consider it superfluous to burden our compendium with more than a very brief review of the same.

It is stated on good authority, that the existence of gold in this State was known to the Jesuit missionaries many years ago; that M. Baric, a Frenchman, actually worked an auriferous quartz vein in 1843, near the mission of San Fernando, and that some British naval officers brought some fine specimens of gold-bearing quartz from this region nearly forty years ago. Hakluyt's account of Drake's voyage to this coast in 1579, states that at Drake's Bay, twenty miles north of the Golden Gate, gold or silver in reasonable quantities could be found in any of the earth—evidently a fabrication. In 1802, it was reported that silver was found in Monterey county, and in 1828, that gold had been discovered in San Diego county; but in 1835, Forbes wrote that no minerals of importance had been found in Alta California. Dana, who traveled through Upper California with Wilkes's expedition, in 1842, speaks, in his work, of the existence of auriferous quartz in Southern Oregon and in

the Sacramento basin, remarking, too, its resemblance to other gold districts. Thomas O. Larkin, United States Consul at Monterey, in 1846 wrote to the then Secretary of State, that at San Fernando, (Los Angeles,) from one dollar to five dollars a day in gold could be made by washing certain black sand, which few have the patience to look for. He also stated that gold, silver, quicksilver, copper, lead, sulphur, and coal mines were to be found all over California. On the fourth of January, 1848, James W. Marshall discovered a piece of gold at the lower end of a tail-race that had been dug at Sutter's Mill, Coloma, El Dorado county. Sutter, Marshall, and Humphrey then formed a mining copartnership. Marshall and Peter L. Wimmer, in the succeeding month, went to Mormon Island, and found gold there. Other parties, residing in different portions of California, hearing of the gold discoveries, visited Coloma, observed the "indications," noted the gold-washing process, and returning home, prospected their neighborhoods with success. Thus the extent of the gold-bearing region soon became apparent, and the newspapers teemed with accounts of wonderfully rich discoveries. Then, from all parts of the world commenced an hegira toward far-off California, such as had never been chronicled in the records of mankind; and ere long, thousands and thousands of hardy adventurers were busily plying the pick and shovel and extracting gold from a region of auriferous alluvium, some four hundred miles in length and one hundred in breadth. At the close of 1849, United States Commissioner King estimated that fifty-five thousand miners were at work in the gold-fields, that forty million dollars had been taken, and that in the succeeding year, 1850, the probable yield of gold would be fifty million dollars.

Most people in the Eastern States and Europe imagined that Mr. King's estimates originated in a vivid imagination; but they were below instead of above the mark. Hittel estimates the gold yield of this State as follows:

1848,.....	\$10,000,000
1849,.....	40,000,000

1850,.....	\$50,000,000
1851,.....	55,000,000
1852,.....	60,000,000
1853,.....	65,000,000
1854,.....	60,000,000
1855,.....	55,000,000
1856,.....	55,000,000
1857,.....	55,000,000
1858,.....	50,000,000
1859,.....	50,000,000
1860,.....	45,000,000

Total,.....\$650,000,000

The gold yield since this date may be estimated as follows:

1861,.....	\$40,000,000
1862,.....	40,000,000
1863,.....	35,500,000
1864,.....	37,000,000

Making a total of,.....\$152,500,000

Add amount from 1848 to 1860,..... 650,000,000

\$802,500,000

Professor Whitney, the California State Geologist, in a work published in 1854, after carefully examining all the statements made by the California bankers and others, and the amounts deposited each year in the mints, divides the gold yield, up to 1854, (exclusive,) as follows:

1848,.....	\$5,000,000
1849,.....	20,000,000
1850,.....	45,000,000
1851,.....	65,000,000
1852,.....	62,500,000
1853,.....	62,500,000

Total,.....\$260,000,000

Although the two estimates differ very greatly when the yields for each year are compared, yet it will be observed that the two aggregate estimated yields for the six years do not differ so considerably, Whitney placing it at \$260,000,000 and Hittel at \$280,000,000; but as a vast amount of gold is taken away each year in private hands, of which no record is kept, it is impossible to estimate with any nicety. In reference to the future yield, Hittel thinks it will gradually decrease to \$30,000,000 per annum, and remain at that figure for a long time; and the silver yield will gradually increase. There is no question in our mind that the latter assertion will prove correct, as extensive and valuable silver lodes have been discovered in various districts in this State and adjoining territories, large amounts of capital invested in their partial exploitation, and sufficient time has not elapsed for the fair development of these mines; but as regards the decrease in our gold yield, we have some doubts, as that depends very materially upon the seasons, as may be seen at once, when we state that the winter of 1852-3 was the wettest ever experienced in California, and the most prolific in gold. As a rule, the drier the winter season the less gold is extracted, and *vice versa*. The excitements of late years, in regard to silver, copper, and coal mining, have had a diminishing effect upon our gold product, as these new and valuable discoveries have diverted a very considerable number of our miners from gold-searching, to prospecting for and working in silver, copper, and coal mines. Other causes we might cite, to prove that California, although she may be at present yielding less gold than formerly, is capable of yielding as much; and if our judgment is not mistaken, we shall see, within the next year or two, a large increase.

The San Francisco *Price Current* gives some valuable tables, showing the production and export of gold from that port. The shipments for 1864 are the largest for eleven years, and stand as follows:

1854, exports to all points.....	\$52,045,633
1864, " " "	54,707,201
Increase,	\$2,661,568

Exports for eleven years :

To eastern ports,.....	\$353,975,269
To England,.....	122,742,471
To China,.....	32,846,497
To Panama,.....	5,646,397
To other ports,.....	4,202,900

Total,.....\$519,413,534

The following are the receipts of treasure at this port, from the interior and coastwise, through regular channels, the records of which are accessible, also the importation from foreign countries, during the past three years :

	1862.	1863.	1864.
Rec'ts from int.,.....	\$42,539,799	\$45,327,326	\$45,460,415
Rec'ts from n'th coast, ..	4,931,579	4,976,023	8,052,368
Imports, (foreign,)....	1,904,084	2,156,612	1,715,024
Total,.....	\$49,375,462	\$52,453,061	\$55,228,407
Exports,.....	42,561,761	46,071,020	55,707,201

Cur'cy movem't,inc. \$6,813,701 in.6,382,041 dec. 476,794

The last year's receipts from the north coast include the sum of \$1,175,000 from British Columbia, which is but little in excess of the amount of 1863. As is well known, however, a much larger amount of treasure, in private hands and to private consignment, is received from the north coast than from any other mining region tributary to the city. The aggregate receipts from that quarter have probably exceeded \$10,000,000, as against \$7,000,000 last year. Our estimate of twenty-five per cent for treasure in the hands of passengers and miners on board the steamers from Victoria and Portland is, we think, quite within bounds.

From the silver districts, the total receipts for the past year were \$15,900,000, against \$12,433,915 in 1863. The increase over last year presents a gratifying exhibit of the growing prosperity of Nevada, but falls much short of the expectations of the sanguine. The receipts were from the following localities :

Virginia City, \$10,425,350	Carson, \$1,994,884
Gold Hill, . . . 1,402,396	Silver City, . . 229,000
Aurora, 960,000	Dayton, 220,000
Humboldt . . . 90,000	Reese River, 500,000

From the south coast, the receipts amounted to \$250,000 through regular channels, and probably fifty per cent additional in private hands. Nearly all the treasure sent hither from the interior of this State and Nevada arrives by public carriers, whose records may be seen, and a close approximation can be made of the actual amount received. From Grass Valley, \$100,000 per month probably come in the hands of private individuals, and from Mariposa, about \$50,000 monthly. These will cover nearly all the outside arrivals. We have, however, heretofore added ten per cent to the receipts of uncoined gold and silver from the northern and southern mines, to cover the amounts received through private channels.

The manifested exports of treasure from this city, for each year since 1849, have been as follows :

1849,	\$4,921,250
1850,	27,676,346
1851,	42,582,695
1852,	46,586,134
1853,	57,331,034
1854,	51,328,653
1855,	45,182,631
1856,	48,887,543
1857,	48,976,697
1858,	47,548,025
1859,	47,649,462
1860,	42,303,345
1861,	40,639,089
1862,	42,561,761
1863,	46,071,920

Total, \$640,237,585

The total manifested exportation of San Francisco, from 1849 to 1864, inclusive—sixteen years—will be \$695,000,000—an average of \$43,000,000 per year. The

manifested export, however, does not show the total production. It is well known that, previous to 1855, large sums were carried away every year by individuals, without report to the Custom-House, and the total amount thus taken has been estimated, by those who have paid most attention to the matter, at \$150,000,000. This would give us a total yield from this coast of about \$850,000,000, of which, however, considerable sums have come from Nevada, Oregon, Idaho, Washington, and British Columbia, and a little from Arizona. The receipts of treasure in this city last year by Wells, Fargo & Co.'s Express, which does nearly all the transportation of treasure, were as follows:

	<i>From Sacramento.</i>	<i>Stockton.</i>	<i>Coastwise.</i>
Uncoined,.....	\$33,936,771	\$5,610,194	\$4,366,510
Coined,.....	3,978,624	1,801,837	603,513
Total,.....	\$37,915,395	\$7,411,931	\$4,970,023
Total uncoined,.....	\$43,913,375		
Total coined,.....	6,383,974		\$50,297,349
Imports from Mexico, etc.,.....			2,156,612
Total receipts,.....			\$52,453,961

Subtract the \$6,383,974 of coin from the total receipts, and we have the sum exported. In the above table, the silver from Washoe, which amounted last year to \$12,413,915, is put down in the receipts *via* Sacramento. The coastwise receipts include about \$125,000 from Humboldt and Crescent City; the remainder, uncoined—\$4,241,000—being from Portland and Victoria. We have now the following foreign elements in the exports of last year:

Washoe,.....	\$12,433,915
Portland and Victoria,.....	4,241,000
Mexico, etc.,.....	2,156,612
Total,.....	\$18,831,517

Subtract that sum from \$46,071,920, the total exportation of last year, and we have \$27,240,403 as the amount of California gold exported.



Fig. 18.—MINING SCENE.

PLACER-MINING, ETC.

IN another portion of this work, we have spoken of mining, as carried on by tunneling and shafting. Placer and hydraulic mining will now briefly engage our attention. Herewith we present a wood-cut, showing the *modus operandi* of gold-mining by tunnels, drifts and shafts, by the hydraulic method, and by the pick and shovel in shallow diggings. In the background of the mining scene will be observed a water-flume, and near it a string of sluice-boxes, into which the miners are throw-



Fig. 19.

ing auriferous dirt. To the left, some miners are tearing into the heart of the hill, with their water-jets. Next, to the right, are others working with a "tom." Two more are engaged at the windlass, over a shaft which their hidden partners are sinking; and beyond them are two men shoving a

loaded car along the tramway, which leads from a tunnel in the hill; whilst in the foreground are others working the "rocker," and "panning out."



Fig. 20.

The first implement generally used in California for gold-washing was the simple pan. This was followed by the Georgia "rock-er," which is now used very seldom, unless

by Chinese, with whom it is a favorite machine. It is very handy for prospecting, on account of its extreme portability. The next improvements were the short and long "tom"—a shallow box with a perforated sheet iron bottom, (shaped somewhat like the letter V,) through which the water, fine dirt, and gold run into a sloping riffle-box beneath; the large stones being left upon said bottom, from whence they are shoveled away. The "tom" is of various lengths; from six to twelve feet as a general thing—and is in communication with sluice-boxes, into which the dirt is thrown by the miner, and thus swept down into the tom by running water. Nevada county, California, is, we believe, entitled to the honor of working the first "sluices," which have since been adopted everywhere. The sluice-boxes are each made of three pine boards, with three cross-slats (one at each end and one in the centre) of the open top. A series of these, resting upon posts or trestles, are fitted into one another, and are then called "a string of sluices." A slope or grade of three inches (more or less) is given to the boxes, and at the points where they fit into one another, they are "caulked" with old rags and tough clay, so as to prevent leakage. The trestles are placed under the head of every sluice-box, and thus also support the tail or end of the preceding box. Across the inside bottom of the boxes, near the head, are tightly fitted slats about an inch deep. These are called "riffles," and here the gold is caught, sometimes with, and at others without

the aid of quicksilver. There are an infinite variety of "riffles" used, but these are the simplest, and by no means the worst. As this is the most common mode of gold-mining in this State, for persons without capital, we will give a closer description of it, and matters connected therewith.

Fig. 21.—SLUICE-MINING—LONG TOM.



We will suppose that Peter, James, and John are out on a prospecting trip. They have with them their picks, shovels, blankets, and pan, besides their provisions, a frying-pan, and tin cups. They reach a creek, dig down for the bed-rock, and reach it at a depth of seven feet. Filling the pan with dirt, one of them "pans out" a prospect, which, if converted into coin, would be represented by three cents. At a distance of two feet from the bed-rock, they try some more dirt, which gives one and a half or two

cents, and from that up to the surface, they find pros-

peats gradually dwindling down to a mere speck, commonly called "the color." They are in "luck," for these are good diggings. They "stake off" their claims—generally one hundred feet in length to each man, and the whole width from bank to stream. Peter at once starts off to the nearest town to purchase sluice-lumber, nails, a sluice-fork, an axe, quicksilver, and more provisions. Meanwhile, James and John dig a ditch to lead a "sluice-head" of water from the creek to the head of their claims. Peter returns with the lumber, etc., and the ditch being finished, (the water, however, not yet running in it,) they make the sluices and "set them," (on the ground, if it slopes downward sufficiently,) and, every thing being in readiness, let on the water. Peter and James now commence on each side of the lower sluice-box to dig down to the bed-rock, throwing the dirt into the sluice. John is engaged in "stripping" or digging away the top dirt at some little distance ahead of his comrades, so that they will have a less depth of dirt to dig when they reach where he commenced. Now and then he looks down the sluices, and if they are getting choked so that the water is running over their sides, he seizes the fork and "forks out" the rocks; if he thinks there is too much or too little water running in the boxes, he takes his shovel, and proceeding to the head of the ditch, regulates the supply as he may desire; now and then, too, he sprinkles quicksilver in the upper boxes. Thus they work until Saturday evening, when they leave off digging for the purpose of "washing down" and "cleaning up." John takes the fork, and proceeds to travel along the boxes from the lower to the upper ones, forking out the rocks, Peter and James assisting him by heaving out the largest with their hands. When the gravel and sand have been greatly reduced in quantity, James goes to the place where the ditch joins the creek, and at a signal from John, shuts off all but a couple of inches of water. Peter then takes a brush and scraper, with which he brushes and scrapes the amalgam and black sand down to the riffles in each box. The water is then entirely

shut off, and the quicksilver, amalgam, and sand is taken carefully out of each riffle and "dumped" into the pan. It is then "panned out," and the quicksilver squeezed through buckskin or stout drilling. The amalgam thus expressed is retorted or placed in an iron pan upon the fire until the quicksilver has evaporated, leaving nothing but the gold. If Peter, James, and John have worked hard during the week, they will probably feel pretty good about this time, when they see the golden result of their labor. The last operation is weighing the gold and dividing it—and whilst they are doing this, we will bid our quondam friends adieu!

We have spoken more in detail concerning ravine or creek-mining, because new-comers almost invariably commence operations in this class of diggings, so as to "get their hand in," or until they have time to look around, and work or purchase into more extensive diggings knowingly. Besides the common sluice, above alluded to, there are the tail-sluice, the ground-sluice, and the rock-sluice. The tail-sluice is a string of boxes, much larger than the others, and similarly fitted together. A few large rocks are placed on the bottom at intervals from one another, so as to catch the sand and gravel that comes from the sluice-boxes. About once a month they are "cleaned up." The rock-sluice is used for hydraulic mining. It is completely covered at the bottom with stones, so as to imitate the bottom of a stream, and requires to be of large size, and to have a steep grade, about one inch to each foot, with a large head of water. The cobble-stone pavement on the bottom of these sluices, is held down by slats. Care must be taken to make the stones overlap one another downstreamwards. It is considered by parties who have long used these sluices, that they save far more gold than any others. The ground-sluice is cut into the bed-rock, whether that be hard rock, soft rock, or tough clay, and into this is thrown (or washed) the dirt above it. This is seldom used, except where the diggings are poor or very shallow. The "under-current sluice" is also coming into use in some parts of the State. Mr. Dunning, who



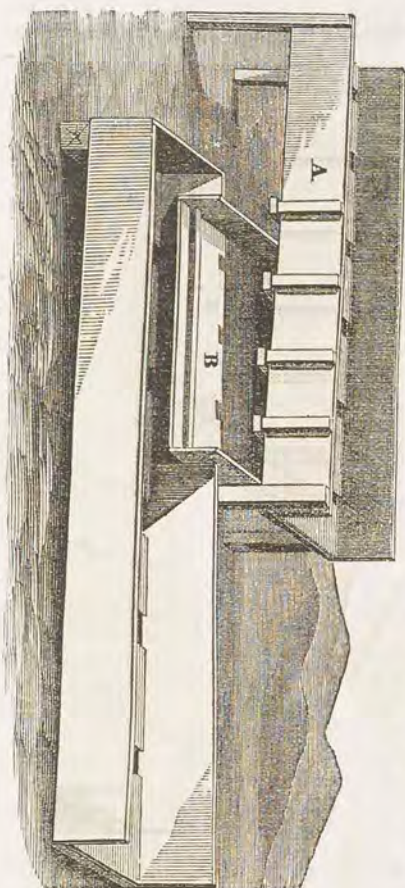
Fig. 22.

invented and introduced it at North San Juan, California, speaks of it thus: By means of two or more iron bars at the termination of a section of sluice-boxes, forming a right-angle grating, a portion of the dissolved earth, fine gravel and water is separated from the lumps of hard earth, cobble-stones, and gravel, and drops into a set of more gently graded sluice-boxes be-

neath, when they flow slowly off in another direction, while the body of the water and coarse material dashes down a "dump" or "fall," to be again taken up in sluices with the tailings from the under-current, and subjected anew to separation. This process insures a more thorough amalgamation and saving of the particles of gold, the most of which drop through the grating into the under-current, where, being subjected to a less violent motion, and passing through a greater variety of riffles, they are more likely to be finally arrested.

In diggings that contain clay, it is necessary to be very careful. The string of sluices must be very long, and not too steep, and their contents well worked with the fork and shovels. Often have we seen among the tailings of careless miners, round lumps of clay, which had come through the boxes, collecting and stealing the gold from the bottom as they rolled! Where the clay is very tough, it must be thrown into a "puddling-box"—a large wooden trough with a hole, a few inches from

FIG. 23.—DUNNING UNDER-CURRENT SLUICE.



the bottom — and soaked. Here it must be worked about and dissolved. The water is then drawn off, and auriferous sediment thrown into the sluices, or panned out.

The most extensive description of mining, is that by the hydraulic process, first applied by Mr. Matteson of Nevada, California. Whole mountains are torn into, and "razeed" by this process. It consists simply of a strong hose and pipe, leading water from a great elevation, and "squirting" it at the gravel and dirt which are carried away through sluices.

In river-mining, the companies owning adjoining claims, generally club together and build a large flume, into which they turn the river by erecting a strong wing-dam of logs, rocks, leaves, mud, gunnybags, etc. In this way the bed of the river is left comparatively dry, and can be worked. The sluices lead to

the flume, and sometimes the water running in the flume is made to turn undershot wheels, connecting with ma-

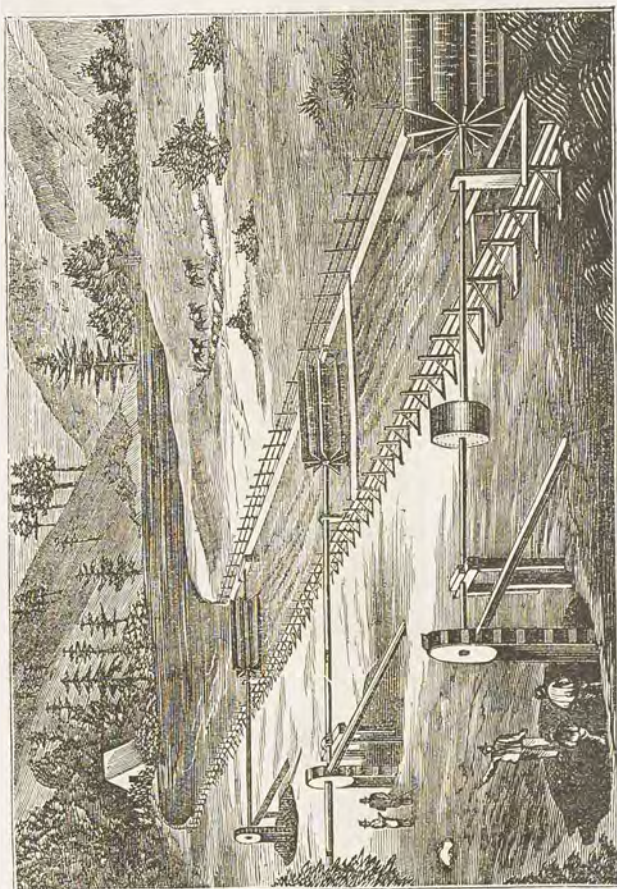


Fig. 24.—FLUME-MINING.

chinery to pump the claims dry to the bed-rock. Large boulders are met with in this class of diggings, and it be-

comes necessary, in addition to the crow-bars and other usual implements of mining, to have a derrick, with which to remove the heaviest rocks. Matteson's patent hydraulic derrick is the most convenient and valuable for this purpose; and we have therefore had an engraving

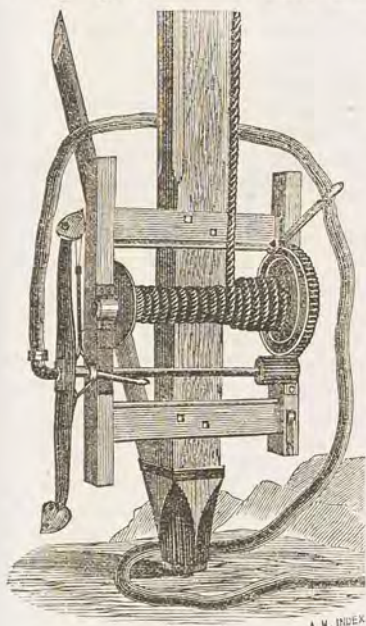


Fig. 25.

of it made, (see Fig. 25,) the principle applied, being also capable of application to an infinite variety of purposes, for wherever water is cheap, the principle of hydraulic pressure, by Matteson's method, can be brought into play, impelling any fixed machinery, at far less cost, and with less risk to property and life than steam or any other motive power. Although not entirely original with him, yet the patentee has introduced great improvements in his machine. We will briefly describe it, as applied to the derrick. The water is conveyed through hose into a tube, from which

it is forced into the centre of a hollow S-shaped casting, called "the wheel." The water rushes in opposite directions from this point, through the curved arms, which are open at the end. The discharges, as in the case of the fire-works known as Catharine wheels, cause the arms of the wheel to revolve with more or less velocity, at the option of the person in charge, who governs the same by opening or shutting the gates that are attached to the apertures. This "regulator" is, as will be seen

in the engraving, very ingeniously yet simply contrived, the gates being connected by rods with a lever. The wheel is on an axle-bar, at whose other extremity is a cog-wheel which fits into another cog-wheel, and thus turns the revolving drum to which the hoisting-rope is attached. The power of the wheel and its speed, can be governed in a variety of ways, independent of the regulator. The power is increased, but the speed diminished by lengthening the arms of the wheel, and *vice versa*. The power and speed are both increased by enlarging the apertures of the arms, and increasing the "head" of water; both are also increased by a larger amount of "fall," or in other words, by taking the water from a higher elevation. Water power can be applied by this method in less time, at less cost, and with more satisfactory results than by any other. Matteson's machine costs one quarter less than an overshot water-wheel. It can easily be taken down and removed to places inaccessible to other machinery. It is so simple in its construction that any one can work it; and is not liable to get out of repair. If it does, the repairs cost but little, and can be done rapidly. One of these derricks is now operating at Nevada City, California. It has a six-foot wheel, with one and a quarter-inch escape-holes, working under a sixty-foot pressure, and using but four inches of running water, conveyed into a tank or reservoir, which is drawn from while the wheel is at work. This wheel is of three-horse power, and can do as much as fifteen men turning the crank of an ordinary derrick. With such great advantages, no wonder that it is becoming a favorite in the mines, wherever it has been put in operation. But, as we before remarked, it is equally valuable for other purposes: for running air-fans in tunnels, circular saws, planing machines, quartz-mills, and, in fact, almost any kind of machinery, where the proper fall of water can be had, and in those towns and cities where water is laid on, it can readily be applied to printing-presses. We have seen a miniature model, from which our drawing was made, which, when connected with the water-pipe faucet, raised a weight of fifty pounds! From this, some

idea of its immense capacity may be formed. The inventor of the "hydraulic derrick" is the same gentleman so justly famous for his application of hydraulic power to mining operations.

Tunnel and shaft-mining, as well as blasting, being treated of elsewhere, we now turn our attention to

PROCESSES FOR THE REDUCTION OF GOLD.

GOLD.—After quarrying auriferous quartz, the reduction processes generally consist simply in pulverizing the rock, and separating it from the gold therein contained. The quartz is first carted from the mine to the platform in front of the mill, where it is broken into small pieces about the size of one's fist or less. Another man, if the mill be a large one, then shovels the broken rock into what is called the "feeder"—a sloping box, down which the rock slides into the bed-plate and beneath the stampers. Water-pipes lead small streams of water into these feeders, if "wet crushing" be the process, but not when the quartz is crushed dry. The dry process is getting quite popular in certain portions of the State. And here we may remark, that there are many different styles and classes of quartz-mills, from the four or five stampers up to thirty-six or more.

The stampers of quartz-mills are methodically raised by "cams" or arms, attached to a revolving iron bar called the shaft, which is turned by water or steam-power. As each stamper reaches a certain height, the cam revolves from beneath it, so that it falls with all its weight upon the quartz on the iron plate. The stampers being heavily shod with iron, and weighing many hundreds of pounds, crush the quartz very fine. In wet-crushing the fine quartz, gold and water are, by the action of the stampers, splashed violently against fine wire sieves, through which the matter, when pulverized sufficiently, passes. When the matter is discharged from these screens, it falls into a sloping box, in which is placed a dash-board, from whence it flows down a series of inclined boards (like sluice-boxes, only much smaller

and with more "fall") which are covered with blankets, in the wool of which the richest tailings deposit. At the junction of each series of "blanket-boxes" are variously contrived amalgamation boxes, so arranged that the descending tailings are forced through the body of quicksilver therein contained. At the head of the inclined boxes a stream of clear water (sometimes *warm*, to assist amalgamation) runs into each box, to assist the tailings in their descent. In well-regulated mills a man known as the "amalgamator" takes up the blankets, one after the other, and washes them in a large trough or box, containing water, replacing them with others; occasionally too, he washes a blanket over a wide shallow wooden pan or bowl, called a "battea," and panning out, ascertains pretty accurately how the rock in process of reduction will yield. In some mills the tailings, after passing over the blankets and through amalgamating boxes, fall into a "Chili Mill"—which consists of two iron wheels, running on one shaft, in the centre of which is a revolving pivot-shaft. In this manner the two wheels are made to run around a small basin, into which the auriferous tailings are washed; at the corner end of this basin is an aperture, through which the light tailings again escape, and are then conducted (in some mills) into an "arastra." The arastra consists of a revolving upright shaft to which two or four horizontal arms are attached. To each of these arms a large oblong piece of granite is appended by iron piles and chains, the front of these granite blocks being elevated about an inch from the bed whereon their rear ends rest, so that the tailings can be caught beneath each block and crushed as they are dragged around in the circular area, which is paved with flat stones cemented together by tough clay. Quicksilver is occasionally sprinkled into the arastra as it works, so also in the Chili mill. The advantage of both these machines consists in the fact that they grind the quartzose matter to an almost impalpable powder and amalgamate at the same time. From the arastra the fine tailings are conveyed away through the last series of boxes, which are well supplied with "fancy"

rifles, while at the end of the whole is some patent amalgamator. About once a week, the battery, blanket-boxes, amalgamators, Chili mill, arastra, etc., are cleaned up, and the sulphuret separated from the amalgam and quicksilver. The amalgam is then parted from the quicksilver by means of buckskin, the latter being squeezed away from the former. The amalgam is then retorted, and the gold is ready for sale or smelting.

HYDRAULIC MINING.



Fig. 27.

The localities in which the auriferous gravel occurs are often high up on the mountains, and far removed from a sufficient supply of water. The works undertaken to supply this defect are sometimes on an enormous scale, the "ditches" sometimes reaching seventy miles in length, in some places clinging to the sides of the mountains, in others, cut through the solid rock, and in others, traversing the valleys by aqueducts of several hundred feet elevation. In Fig. 28, representing the Magenta flume, besides the main aqueduct, two smaller ones are shown at lower levels. The length of the Magenta flume, which is near Eureka, in Sierra county, is fourteen hundred feet, and its greatest height one hundred and twenty-six feet. The water is brought in at an elevation

twenty-six feet. The water is brought in at an elevation

of from fifty to two hundred feet above the bed-rock, and conducted by means of iron pipes and strong hose, to the point where the jet is to be directed against the



FIG. 28.—HYDRAULIC FLUME.

hill of gravel which is to be cut down. The hose is made of heavy duck, sometimes double, sewn by machinery, where the height is not more than fifty feet, but when it is greater, the hose requires to be surrounded by rings of iron about two inches wide, placed about three inches apart, and it will then support a pressure of one hundred and fifty to two hundred feet of water. The nozzles used are like those of a fire-engine, but from two and

a half to three inches in diameter. Fig. 53 shows an improved coupling, invented by Messrs. Smith & Lowe, for connecting the sheet-iron pipes, by which the water is brought down to the bottom of the workings, with the flexible hose. It consists of a strong iron box with attachment for several hose, and fitted with slide-valves

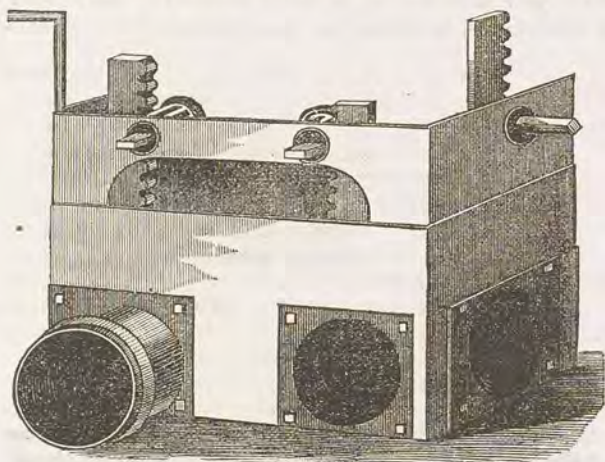


Fig. 29.

worked by racks and pinions. Fig. 30 gives a general view of the operations of hydraulic mining. The stream is at first turned upon the bottom of the bank, so as to undermine it. The great masses of earth thus brought down are then washed by the same means, which soon removes all the smaller materials, only the largest boulders being left, which are taken out of the way, if necessary, by means of a derrick. In Fig. 30, one of Matteson's hydraulic derricks is shown in the foreground. The mingled flood of water, gravel, and pebbles is carried through an extended series of sluices, some cut in the bed rock and paved with blocks of stone, and others in plank, with wooden riffle-bars, in the interstices of which a small quantity of mercury is placed to aid in

detaining the gold. It sometimes happens that the amount of water employed in breaking down the hill is more than sufficient to wash the dirt obtained; and, in that case, the action of the water is assisted by blasting down portions of the bluff, or it is partially undermined by hand labor, and the columns of earth left to support the bank are then washed away by the jet. At intervals of ten or twenty days, according to the size and richness of the work, the process of "cleaning up" is performed, which consists in removing the pavement of blocks of wood or stone, and collecting all the amalgam and rich dirt which has been caught between them. The economy of human labor effected by the hydraulic method of mining is so great, that Mr. Black, of San Francisco, in his "Report on the Middle Yuba Canal, and Eureka Lake Canal, Nevada County, California," in 1864, estimates that while the average cost of handling a cubic yard of auriferous gravel with the pan is twenty dollars, with the rocker five dollars, and with the long-tom one dollar, with the hydraulic process it is only twenty cents. The measuring-box is used for distributing the water from the main aqueducts to the different workings which they supply. This consists of a wooden box, in three sides of which slits, generally two inches wide, are made, closed by sliding valves. A graduation into inches on the side of the box, above the slide, enables the quantity of water which escapes to be exactly measured. In California mining parlance, an "inch of water" is that quantity which will pass through an opening of one square inch in area, under a mean pressure or head of six inches of water. Thus, if the slit is two inches wide, and is opened twenty-five inches, fifty inches of water will flow out.

METALLURGY OF GOLD.

GOLD, so far as we yet know, always occurs in nature in a metallic state, and not in the form of oxides, chlorides, sulphurets, carbonates, etc., like most other metals. The only exception to this, is in the case of certain rare minerals containing Tellurium. From some ores, too, containing gold in connection with iron pyrites, so small a proportion of the gold can be extracted by the ordinary processes of crushing and amalgamation that some chemists have been of the opinion that at least a portion of the metal exists in them in a state of chemical combination, probably as a sulphuret. No sufficient evidence of this, however, has yet been obtained, and it seems probable that the union, though very intimate, is merely a mechanical one. Most of the ores of the Colorado mines belong to this category, and very numerous attempts have been made to overcome the difficulties encountered in obtaining from them the entire amount of gold which they contain; but hitherto, with but imperfect success, so far, at least, as has been made known to the public. A natural amalgam of gold and mercury also exists, but is a very rare mineral. In consequence of this almost universal occurrence of gold in a metallic state its metallurgy is exceedingly simple, almost all the processes resolving themselves into friction in contact with quicksilver.

Three principal modifications of the amalgamation process are employed; 1st, amalgamation in the battery; 2d, amalgamation in the arastra; 3d, amalgamation in iron pans.

AMALGAMATION IN THE BATTERY.

For this purpose the sides of the box, containing the stamps, is provided with amalgamated copper plates, three to five inches wide, and of the same length as the battery; one at the discharge, the other at the feed side, the latter being protected by the iron feed-plate. These are fixed with a pitch of 35° or 40° toward the dies. Other batteries have a somewhat different arrangement of the amalgamated copper plates. The plates are amalgamated by rubbing quicksilver on the copper with a piece of cloth, moistening it previously with a few drops of nitric acid, slightly diluted with water. The quantity of quicksilver employed upon the amount of gold in the ore, about an ounce of quicksilver to each ounce of gold is the ordinary proportion, but when the gold is very fine, $1\frac{1}{4}$ to $1\frac{1}{2}$ ounces may be used. Quicksilver is introduced by degrees during the stamping, the quantity being regulated by the character of the amalgam produced. If this appears very hard and dry, more quicksilver may be used, but if on the contrary the amalgam is very soft, or if drops of quicksilver appear, the quantity must be reduced. Mr. Küstel states, that when the operation is properly managed, from 60 to 70 per cent may be saved in the battery, when the ore contains heavy gold, "but light gold, (300 to 400 fine,) like Washoe gold, gives a less favorable result. A great many fine particles of amalgam adhere together, involving also manganese scum, if present, and form small spongy, blackish lumps, which are so light as to float, and on account of being coated with foreign matters, will not unite with the amalgam. Of this amalgam but very little can be saved; it floats over blankets, copper plates, or ripples.

"It is therefore an error to use quicksilver in the battery, if concentration is in use, and the tailings are not saved. The finest gold is easier retained by concentration than this floating amalgam. There is also no evidence of any advantage in battery amalgamation, when the whole mass of pulverized rock is amalgamated in

pans, unless the mass of the concentrated part is intended for roasting."

AMALGAMATION IN THE ARASTRA.

This is a very old method, but under proper management gives very good results. The arastra consists of a circular bed-stone of hard granite, surrounded by a wooden tub, in the centre of which is supported a vertical shaft, which carries the mullers by which the grinding is effected, and is supported at its upper extremity by a horizontal beam, to which the upper pivot is attached. This vertical axis is traversed by two horizontal arms, by which the mullers are supported; and to the extremity of one of them, which is left longer for that purpose, are attached the two mules by which the machine is set in motion when water-power is not to be obtained. The mullers make "from six to ten revolutions per minute, and grind one and one half to two tons of rock (broken in pieces as large as a hen's egg or smaller) in twenty-four hours. This is, however, too much for a proper amalgamation. "When in motion, the arastra is charged with about two hundred pounds of ore, with some water. One quarter of an hour afterward, the balance of the whole charge, from four hundred to five hundred pounds, is introduced. As soon as the ore is turned into mud, one or two ounces of quicksilver are pressed through a dry cloth over the thick pulp. A sample is taken from time to time with the horn spoon, washed and examined. When free gold is perceived, after the amalgamation has been going on for some time, some more quicksilver may be added. The first charges require a little more quicksilver. After four or five hours the pulp is diluted with water and discharged. The next charge is treated in the same way, and so on till one hundred or one hundred and fifty tons are worked through. The quicksilver must be used always in proportion with the gold—one or one and a half ounces to an ounce of gold. The amalgam imbeds in the crevices of the bottom, and must be always dry. The use of too much quicksilver makes the amalgam thin, causes an im-

perfect amalgamation and a loss in quicksilver, which is often found beneath the bottom rock."*

AMALGAMATION IN IRON PANS.

The construction of the common pan, as well as of Wheeler's, and Hepburn & Peterson's pans, will be found under "Metallurgy of Silver." The treatment of gold ores does not differ from that of silver ores, except that neither heat nor the use of chemicals is required. Mr. Küstel states that slow motion is not found to be favorable to the amalgamation; that, although the degree to which the velocity may be advantageously increased is not yet ascertained, about sixty revolutions per minute is found to answer most satisfactorily. Some loss of quicksilver by friction, however, takes place at this speed. He says that, by pan amalgamation, as much as 95 per cent of the quantity of gold found by a fire-assay, is obtained, and that the loss which takes place, does not result from defective amalgamation, but from improper discharge. Ores containing gold in such condition that it can not be liberated by grinding, must be subjected to roasting without salt, before treating in pans.

CHLORINATION PROCESS.

"This process is based on the property of chlorine, which enables it when placed in contact with gold to form a tetrachloride of gold without the application of heat. The silver when in the metallic state, or as sulphate, undergoes the same change, forming chloride of silver; but the chloride of gold is soluble in water, chloride of silver only in a hot solution of salt."†

This process has lately been employed to some extent in California, principally in the reworking of tailings. Coarse gold which, however, is seldom found in the tailings, would resist chlorination, or require too much time; and according to Mr. Deetken, the person who has made most use of this process, gold of a low degree of fineness is preferable, being sooner transformed into chloride.

* Küstel, p. 62.

† Küstel, p. 64.

The tailings are first calcined in a roasting-furnace without salt. When thoroughly roasted, they are spread out to cool and sprinkled with water. The moistened stuff is introduced into wooden tubs about seven feet in diameter and twenty-five to thirty inches deep, having false bottoms, through which chlorine gas can be introduced from beneath. Near the bottom are two holes, one for the discharge of the solution, while, through the other, chlorine gas, generated by the action of sulphuric acid on a mixture of peroxide of manganese and salt, is introduced. In the course of a few hours the whole mass is penetrated, and the greenish gas becomes visible on the surface. The tub is then closed by a wooden cover and left for ten or fifteen hours. The cover is then removed and clean water introduced. As soon as the water reaches the surface of the tailings, the discharge-pipe is opened, and the water containing the dissolved chloride of gold is led into glass vessels. An addition of sulphate of iron precipitates the gold in metallic condition as a black-brown powder. If any silver is contained in the tailings, it is converted by these processes into an insoluble chloride, which remains in the ore. The gold thus obtained is therefore of almost absolute purity, (995 fine, according to Küstel.)

METALLURGY OF SILVER.

THE processes employed for the extraction of silver in California and Nevada, may be described under four heads; 1st, The "Wet Process," (amalgamation of unroasted ores in iron pans;) 2d, the amalgamation of roasted ores, of which three principal varieties are employed, amalgamation in barrels, amalgamation in iron pans, and amalgamation in Dr. Veatch's steam-tubs; 3d, the Mexican or Patio process of amalgamation in heaps; 4th, smelting with lead or lead ores, and subsequent separation of the silver by cupellation. The following descriptions of the peculiarities of these processes as applied to the ores of Nevada and California, especially of the first two, are derived in a great measure from the excellent work of Mr. Küstel, upon the processes of silver and gold extraction in Nevada and California, the most valuable contribution made of late years to this branch of metallurgy.

WET PROCESS.

In this process, which appears to have originated in California, unroasted ore is employed—a very important advantage, as dry crushing, which is very injurious to machinery, is not required. The first pans employed for this process, had their surface so much diminished by a centre-piece and numerous shoes, that only fifty pounds of ore could be worked at once in a four-foot pan, and five or six hours were required to complete the process; but now, a four-foot Wheeler's pan is charged with 750 or 800 pounds of ore, and the amalgamation is finished

in three hours, including charging and discharging. The common iron pan is represented in figures 31 and 32; *a*

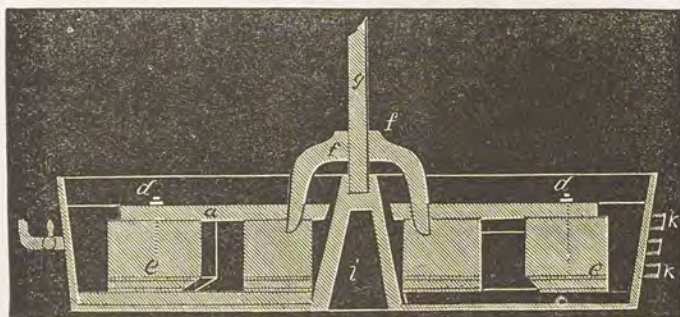


Fig. 31.

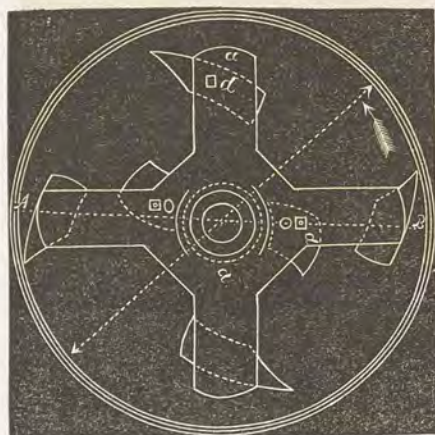


Fig. 32.

is a wooden cross to which wooden blocks, *b*, with iron shoes, *c*, are fastened by the bolts, *d*; each shoe has a pin, *e*, fitting into the wooden block in order to prevent its moving; on the shaft, *g*, is the yoke, *f*; the two ends of the yoke fit in the holes, *h*, of the cross, *a*, but

not too tightly, so that the muller can descend as the shoes wear away. Some pans are so arranged that by means of a screw the muller can be raised; but Mr. Küstel thinks this arrangement not to be of importance, as the muller generally grinds with its full weight. Steam is introduced into the pulpy mass of pulverized ore and

water, through the pipe, *l*; *k k* are discharge-pipes; *m* is a false bottom of iron, made in one piece, two inches thick. Wheeler's pan is represented by figures 33 and 34. For the sake of clearness of representation,

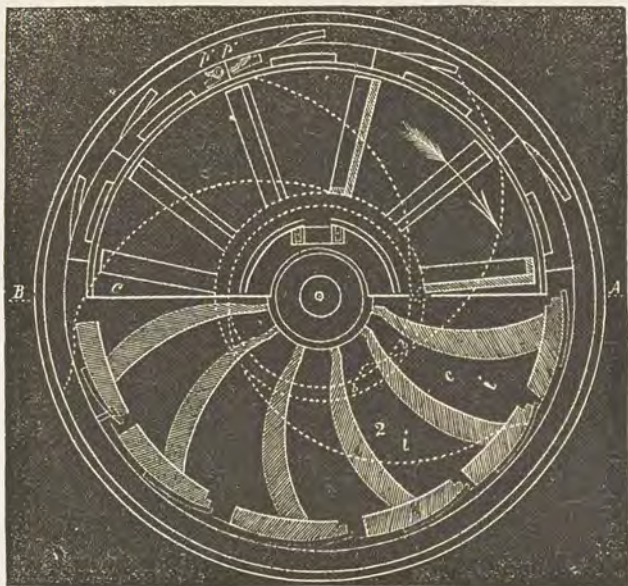


Fig. 33.

the yoke, *a*, and the guide-blade arrangement, *q*, *b'*, *b*, *c*, of figure 34 are not represented in figure 33, but the position of the guides is shown by dotted lines, *e*. In figure 33 the muller, *d*, and the ring, *e*—the two journals of which move in the box, *f*, fixed to the muller, while the other two, *g*, move in the box, *h*, of the yoke, *a*—are represented as covering only one half of the pan, while the other half shows the form and position of the dies, *i*, which replace the false bottom of the common pans. These are laid directly on the bottom of the pan, *k*, and are kept in place in the centre by the ring, *j*, and on the sides by the inclined ledges, *l*; each die has for this purpose a projection, *m*, with

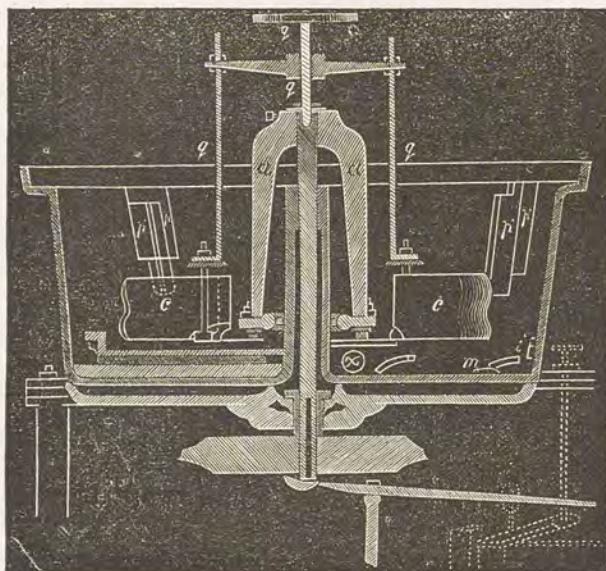


Fig. 34.

the beveled side uppermost, as represented at *m'*, in figure 34. The dies are one inch thick, beveled on one side, so that in putting them together the grooves, *i*, are formed. In figure 34, a side-view is given of the muller, *d*, shoe, *n*, and die, *i*; the muller has twelve oblong openings, *d*, two and one fourth inches wide by ten and three fourths long. One of the long sides toward the dies is beveled, as shown by the dotted lines, *s*, and the shoes have projections of the same shape, but half an inch narrower and shorter, and the space of half an inch is wedged with dry pine wood, *n*, by which the shoe is fastened to the muller; the shape of the shoe below the muller is represented by the dotted lines, *o*, on the outer edge of the muller are inclined ledges, *o*, which in connection with those of the pan, *l*, create an upward current of the pulp; *c c* are guide-blades conveying the pulp to the centre. These guides have at the

outer end a projection, like a hook, as indicated by the dotted lines, *c c*. This hook catches the blade, *p*, which is also bent hook-like, fastened to the pan by an iron wedge between the ribs, *p'*. Thus the guides resist the current of the pulp.

The guide-blades, *c*, are attached to the frame, *q*, formed of four rods screwed to the ring, *b'*, which is connected with the lower ring, *b*, by four bolts to which the guides are attached. The frame rests by means of the screw, *q'*, on the shaft, *r*, and can be raised or lowered at pleasure; *a* is a steam-pipe which conveys the steam directly into the pulp. These pans were formerly made with a steam-chamber—shown at *u*, in figure 32—for heating the pulp through the bottom; but this arrangement did not prove economical, and is no longer employed. The apparatus for raising the muller is shown at *w* and *w'*.

Hepburn & Peterson's pan is represented in figures 35 and 36. It differs from Wheeler's pan mainly in hav-

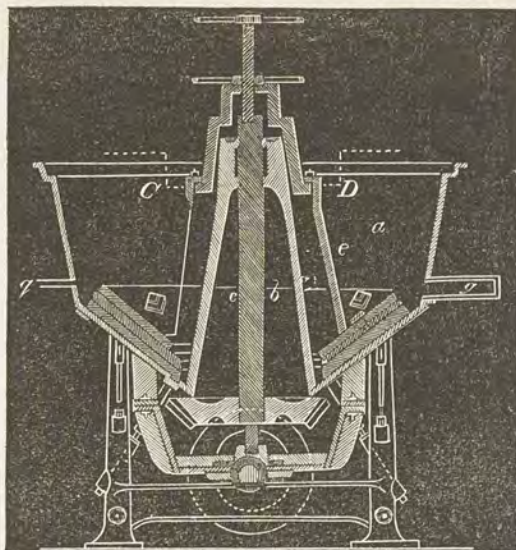


Fig. 35.



Fig. 36.

ing an inclined bottom; a pan which is eighteen inches deep on the side, being twenty-seven inches deep near the hollow cone, *b*, through which the shaft, *c*, passes. The muller, *m*, is connected with the shaft by means of three arms, *e'*, joining at the top into one piece, *e'*, in which three openings, *p*, are made for the passage of the projections, *e*, of the driver, *d*. When the driver is set in its place, it must be turned to the right, so that the projections, *e*, will come under the leveling screw, *x*, as represented in figure 25 by the dotted lines joining the projections, *a*, of the piece, *e*, whereby the motion is transferred from the driver to the muller. The shoes, *n*, are fastened to the muller by the bolt, *m'*; there are also two pins on each shoe which fit in small holes in the muller to prevent motion. In figure 36 these shoes are shown by dotted lines; the pipe, *q*, serves for discharging, and *q'* for introducing steam.

The treatment of ores in iron pans is among the most simple of metallurgical operations. The muller is put in motion, the pan charged with some water and the pulverized ore introduced. A four-foot common pan will take 150 lbs.; a five-foot pan 250 or 300 lbs., and a six-foot pan 450 or 500 lbs. of ore. Wheeler's four-foot pan is charged with 750 lbs. The ore should not be allowed to form too liquid a pulp. If there is too much water, there is not only more friction from the settling of the sand, but the chemicals are more diluted and the

quicksilver gathers into one mass on the bottom, instead of being mingled through the ore, but if, on the other hand, the pulp is too thick, the particles of ore can not change their places quickly enough, and a perfect mixture is thus rendered impossible. After the charging of the pan, the quicksilver is introduced. If salt is used, it may be added immediately after the quicksilver; the pulp should be kept, as far as possible, in uniform condition in regard to dilution and heat. The temperature which seems to answer the best is below boiling heat, but still hot enough to render it uncomfortable to hold the finger in the pulp longer than just to try its condition. Too much heat is injurious, especially when sulphate or chloride of copper is used, causing a larger loss of quicksilver, and also of amalgam, which, assuming a black, rag-like appearance, does not unite easily with the other amalgam, but swims on the quicksilver. After a run of three or four hours, by which time the ore is ground very fine, the pulp is diluted with water, so that all the quicksilver and amalgam can join in one mass on the bottom. The pan has generally three discharge-holes. The uppermost hole is first opened and the tailings allowed to run off for a quarter of an hour, a constant stream of water being kept up. The plug of the second hole is then removed, and the discharge continued for a like period. Both holes are then plugged up, the pan charged with ore, and the series of operations already described is again gone through with. The lowest hole serves for discharging the quicksilver, and is level with the bottom, or even below it. The quicksilver may be taken out once or twice a week, or oftener, according to the richness of the ore. In discharging the tailings, some amalgam is always carried out, especially at the end of the operation, when the coarser sand is washed out. To prevent the loss of this amalgam, agitators are employed. They ordinarily consist of tubs, two or three feet in diameter, and ten or twelve inches high, with a vertical shaft, on which are fixed four arms, carrying stirrers. (See figure 37.) These agitators differ much in construction and size, but none give a very satisfactory result. Wheeler's

agitator (figure 38) has a cast-iron bottom, inclined toward the centre, ending in a bowl, *h*, for the reception of quicksilver, which is always kept full, and when the pans are discharged, the superfluous quicksilver runs

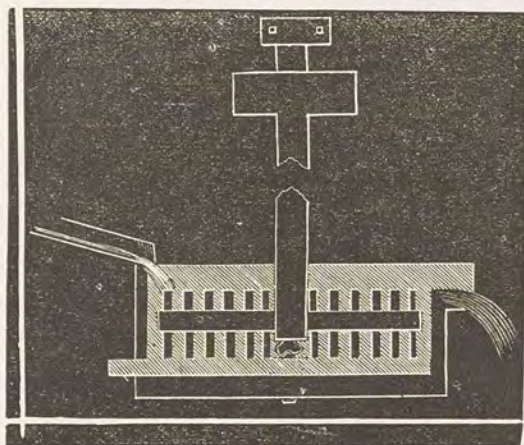


Fig. 37.

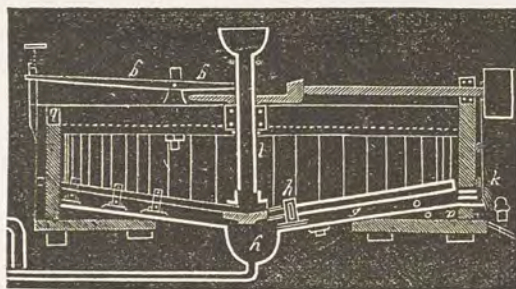


Fig. 38.

out by the siphon, *i*. The tailings flow out constantly, through the pipe, *k*, three eighths of an inch in diameter, and four inches above the bottom. The lower pipe, *l*, an inch in diameter, serves for the discharge

when the agitator requires to be cleaned; *o* is also a discharge-hole. The sides of the agitator are formed of wooden staves, and are twenty-five to thirty inches high. Hepburn's agitator differs from Wheeler's, in having a level bottom, and instead of the bowl in the centre, there is a circular groove near the bottom of the iron circle, connected with a siphon. Wheeler's agitator, being eight feet in diameter, has such a swift motion at its circumference, that when the tailings are treated in the usual way by diluting with water, a great deal of amalgam is carried out. To avoid this, Mr. Küstel adopted the following method. Three or four inches above the bottom the tailings are discharged into the agitator without dilution, unless the pulp is too thick, and flow out of it in a thin stream, through the small pipe, *k*, into a five-foot pan, into which a continual stream of water (an inch in diameter) flows. This great dilution, under a constant stream, admits of a very perfect separation of the amalgam which unites with the quicksilver in the pan. In this way, the quicksilver and amalgam have time enough to sink by degrees to the bottom of the agitator, and those particles which escape through the three-eighth inch pipe are also saved. The amalgamation in Wheeler's pans does not differ much from that of the common pans, except in their peculiarity of discharging the tailings and quicksilver every time. The quality of the shoes and dies has a great influence upon the rapidity and fineness of the grinding. Soft shoes will last from thirty to forty days, according to the quality of the ore, while hard ones, of white iron, will do ten or fifteen days' more work, at the same time grinding better. The only inconvenience of the hard shoes and dies consists in the brittleness of the iron, and care must therefore be taken that they do not become too thin; as, if this is neglected, the introduction of even a small piece of unusually hard material, may cause the shoes or dies to break, which may lead to the fracture of the yoke, or some other part of the machinery. The best working speed is from fifty to sixty revolutions per minute, and this quick grinding is found advantageous

in saving silver ore, because it allows coarser ore to be used in the pan. If it is attempted to crush the ore very fine before entering the pan, much silver ore is turned into slime, of which a great deal is carried out by the water, or if the ore is crushed dry, much will be lost as dust. From the difficulty of working this slime to advantage, coupled with the fact that it is often richer than the coarser sediment, (especially if the brittle sulphurets of silver are present,) it is advisable in using Wheeler's pan to crush coarse and to grind fine. With the common pans it is preferable to pulverize the ore as fine as possible, in order to save time, and to diminish the wear of the bottom. The guide-blades must always be kept close to the muller, in order to prevent the ore and quicksilver from following its motion, thus forcing the mass to the centre, and under the muller. With regard to the use of chemicals, Mr. Küstel says that he found them entirely useless in treating the Ophir ores in Wheeler's pans. In treating silver ore in common pans, however, the use of chemicals always gives a better result. Under favorable circumstances, iron unquestionably decomposes the sulphurets of silver just as well, or better, than any chemicals; but if, on account of imperfect grinding arrangements, the iron is unable to act on the sulphurets sufficiently, the use of chemicals may prove useful. A large number of different substances and combinations have been employed in various mills to promote the decomposition of the ores, but none produce very satisfactory results. Mr. Küstel enumerates sulphate of copper, (blue vitriol,) sulphate of iron, (copperas, or green vitriol,) bisulphate of soda, alum, sulphuric acid, common salt, chloride of copper, subchloride of copper, protochloride of iron, and chloride of iron. He gives also a number of practical receipts for mixtures actually employed in various mills; of these, we quote the four which he seems to regard as most likely to prove useful.

- | | | |
|--------------------------|---------|---------|
| 1st. Chloride of copper, | | 13 lbs. |
| Common salt, | | 60 lbs. |
| 2d. Chloride of iron, | | 13 lbs. |

3d. Sulphate of iron,	1 lb.
Sulphate of copper,	8 lbs.
Common salt,	80 lbs.

These three receipts are calculated for ore containing from 250 to 500 ounces of silver in sulphurets. All chemicals, except salt, are used in solution. The salt is charged half an hour before the chemicals are put in.

4th. Sulphuric acid,	3 lbs.
Sulphate of copper,	2 lbs.
Salt,	15 lbs.

The quantities in these receipts are for one ton of ore.

All silver combinations, however, are not suitable for the wet process. We do not as yet know with sufficient accuracy the behavior of different silver ores in the pans, but the difficulty of decomposition seems to increase with the amount of sulphur in the ore, and to be still greater when antimony is present. Arsenical combinations are more easily worked than antimonial. Where silver is contained in arsenical iron pyrites, or antimonial combinations prevail, the roasting process must be adopted.

ROASTING PROCESS.

Almost all silver ores will yield a larger amount after roasting than when worked raw, although in many cases the saving of labor, and still more, of fuel, in such a region as Nevada, may render it profitable to incur the loss incident to the last-named method. On the other hand, many silver ores may be worked at a great profit, after roasting, which, without it, would yield little or nothing. The object, in almost all the roasting processes, is to convert all the silver into a chloride, which is easily decomposed by the quicksilver, and rapidly becomes amalgamated. Ores, to be roasted, must contain a sufficient amount of sulphur to effect the decomposition of the salt; and if, therefore, the ores are principally antimonial or arsenical, with but little or no sulphurets, an addition of two or three per cent of calcined green vitriol must be made.

The principal reactions which take place in roasting

silver ores with salt, are as follows: The iron pyrites and other sulphurets, when heated red-hot in contact with air, are changed in a great measure into sulphates, a portion of the sulphur being oxydized into sulphuric acid, which combines with the metallic oxyds, while another portion escapes as sulphurous acid. During this part of the process, which is performed at a low heat, no decomposition of the salt takes place; but as soon as the sulphates are formed, and no odor of sulphurous acid remains, the heat must be increased, and the salt then begins to decompose. This occurs in two different ways.

1st. The sulphate of iron, and other sulphates, give off vapors of sulphuric acid, which, in contact with salt, form sulphate of soda, while the chlorine is set free in a gaseous form. This combines with any native metals which may be present, and decomposes the sulphurets in such a way that one part of the chlorine combines with the sulphur, as chloride of sulphur, which volatilizes, while another part forms a chloride with the freed metal.

2d. In the second mode of decomposition, free chlorine is not formed, but the sulphate and the salt mutually decompose each other. Sulphate of silver, for instance, which is composed of sulphuric acid, silver, and oxygen, being heated with common salt, which is a compound of chlorine and sodium, the silver combines with the chlorine, forming chloride of silver, while the oxygen and sodium form soda, which, with the sulphuric acid is converted into sulphate of soda. During these reactions, hydrochloric or muriatic acid, is also produced, when vapor of water is present. The ores intended for roasting must be examined, not only with regard to the quantity of sulphurets, but, also, to the earthy matters accompanying the ore. If there is a great deal of lime in the ore, it absorbs sulphuric acid, forming sulphate of lime, which remains undecomposed through the whole process. Calcareous ores therefore require the presence of sufficient additional amount of sulphurets to change all the lime into sulphate. Talcose ores behave in the same way. Silica or quartz, on the contrary, exercises an

advantageous influence; it is therefore disadvantageous to submit pure calcareous or talcose ores to the roasting process, and in such a case quartzose ores must be added if possible. The quantity of sulphurets in the ore is important, a certain amount being required to decompose as much salt as is necessary for chlorination.

"In Freiberg, (Germany,) it was the rule to subject only that ore to roasting which contained enough sulphurets to give twenty-five or thirty per cent of matt (sulphide of iron) when assayed for that purpose. If less matt was obtained, the ore had to be mixed with other ore, or so much iron pyrites was added that the required quantity of sulphurets was obtained. The second class ore of the Ophir and Mexican claims in the Comstock lode, consisting of pure decomposed quartz, contains silver sulphurets, with a small proportion of iron pyrites, yielding from six to eight per cent of matt. The roasting with salt, however, gives a satisfactory result, which must be attributed chiefly to the pure quartzose condition of the ore.

"If the ore contains an abundance of sulphurets, the roasting must be performed without salt, for about two hours, till the greatest part of the sulphur is driven off, otherwise it would bake, and cause an imperfect roasting.

"The quantity of sulphurets has a great influence on the result of roasting. Ore like that of the Ophir or Mexican mines, containing silverglance, polybasite, brittle silver ore, native silver and gold, some iron, and but little copper pyrites, will give a good result by roasting, even when less attention is paid to the time and diligent stirring, than, for instance, with the so-called 'base-metal ore,' which abounds in copper pyrites, zinc-blend, sulphuret of lead, etc. The presence of base metals causes a higher loss in silver. The chloride of silver is not volatile, except at a high temperature. But it has been observed that, in the presence of base-metal chlorides, the chloride of silver volatilizes also. The increased heat increases the volatilization, but decomposes the base-metal chlorides. By keeping a low heat, the loss

of silver is less if the zinc-blend is not argentiferous, the latter requiring a higher heat to effect decomposition. But in roasting at a low heat, the base-metal chlorides remain in the ore, and cause more loss of quicksilver in the subsequent amalgamation, and require more metallic iron in the barrels; besides, the bullion contains a great deal of base metals. In treating such ore in the roasting-furnace, the application of steam is advantageous, creating hydrochloric acid by the decomposition of chlorides, at the same time becoming a decomposing agent for the sulphurets. The hydrogen of the steam decomposes also the chloride of silver, which, upon being reduced to a metallic condition, by its affinity for chlorine, in turn decomposes the hydrochloric acid. The silver may thus change repeatedly from metallic condition to the chloride, while the base-metal chlorides are reduced to oxyds, and in that state do not interfere with the amalgamation."*

Mr. Küstel gives very full details of the precautions necessary in roasting silver ores to prepare them for different methods of amalgamation, but our limits will permit us only to quote a few of his directions. For fuller details, we must refer to his book, without which, indeed, no metallurgist, not possessed of very extensive personal experience of the ores of Nevada and California, can hope to treat them with success.

Silver ores, intended to be subjected to the modes of amalgamation without friction, (barrel amalgamation and Dr. Veatch's steam-tubs,) must be free from metallic gold, or it must be extracted before the ore is subjected to roasting. After roasting, the gold is not, like silver, in a soluble and easily decomposable condition, but in a metallic state, generally coated with some oxyd, especially if sulphuret of lead occurs in the ore. This renders the amalgamation of gold much more difficult. Metallic silver, also, when roasting is performed without salt, using charcoal and saw-dust for the purpose of converting the silver combinations of the ore into the metallic state, will be imperfectly amalgamated in the bar-

* Küstel.

rels. When ores are intended to be amalgamated in pans, it is not absolutely necessary that all the silver in the ore should be converted into chloride. Consolidated fragments or lumps, formed during the roastings, are not injurious, as with the other processes. The extraction of gold before roasting is not necessary.

"The sulphates remaining in the lumps, and such as were not changed into chlorides by improper roasting, are partly decomposed in the pan by the iron, but most of them are converted into chlorides by the salt, which always remains in small quantities in the ore after roasting. This salt dissolves in the pan and changes the sulphates, which are also soluble, into chlorides, they being decomposed by the iron and amalgamated. The quicksilver, when present in the pan, takes also part in the decomposition, being thus converted into subchloride of mercury or calomel, which, unlike chloride of mercury, not being decomposed by the iron, cause a loss in quicksilver.

"The sulphate of silver, soluble in hot water, will be decomposed by iron into metallic condition, combining with the quicksilver to form an amalgam. It would appear, therefore, that roasting without salt, for the purpose of producing sulphate of silver, which is easily beneficiated in the pans, would be more economical by saving salt. It is, however, very difficult to transform all the silver into a sulphate."

"The chloridizing roasting requires less attention, and gives a better result. The sulphurets which may remain in the ore undecomposed after roasting, will be reduced in the pan by predominant chlorides and sulphates. Sulphates alone effect very imperfect decomposition of sulphurets in the pan."*

BARREL AMALGAMATION.

A very good account of this process, as practiced in Europe, is given in Phillips's Metallurgy, which may be quoted here, as it scarcely differs from the methods adopted in Nevada.

* Küstel.

The amalgamation of silver ores is perhaps more systematically and economically conducted at Halsbruecke, in the vicinity of Freiberg, than in any other European locality. The usual constituents of the ores there treated are sulphur, antimony, arsenic, silver, copper, lead, iron, and zinc, which are more or less mixed with various earthy minerals, besides sometimes containing small quantities of bismuth, gold, nickel, and cobalt. In the selection of these ores, they are so assorted as not to contain above 7 per cent of lead, or 1 per cent of copper, as from combining with the mercury added, these metals give the amalgam a pasty consistency, and thereby render the treatment extremely difficult and expensive. The mixture of the different ores obtained from the mines is so arranged that the charges of the furnaces shall contain seventy-five to eighty ounces of silver to the ton of mineral; it is also essential that they should contain a certain proportion of sulphur. This usually exists in the form of iron pyrites, which, on being roasted, gives rise to the formation of the sulphate and oxyd of iron necessary to the success of the subsequent operations. If, as is sometimes the case, the amount of pyrites naturally occurring in the ores is not sufficient for these purposes, addition is made either of this mineral, or, in some instances, of ready-formed sulphate of iron.

The ore, when thus prepared, is laid on a large floor, forty feet in length and about twelve in width, and on the top of it is thrown about ten per cent of common salt which is let drop from an upper room, through a spout placed in the floor for that purpose. The heap, when it has been thus made up of alternate strata of ore and common salt, is well mixed by being carefully turned over, and is subsequently divided into small parcels called *roast-posts*, each weighing from $3\frac{1}{2}$ to $4\frac{1}{2}$ cwts. The salt annually employed for this purpose at the Halsbruecke works amounts to three hundred tons, and is supplied by the Prussian salt-mines.

The mixture of ore and salt is now roasted in reverberatory furnaces provided with fume-flues for the reception of any pulverulent matters which may be mechani-

cally taken over by the draught. The prepared charge is spread on the bottom of the hearth, where it is at first very gently heated, for the purpose of expelling the moisture, which to a greater or less extent it invariably contains. During the process of drying, which usually occupies two hours, the charge is kept constantly stirred by a long iron rake, and when this operation is considered sufficiently advanced, the heat is so far increased as to cause the ignition of the sulphur, and to render the ore red-hot.

The furnace is kept at this temperature for about four hours, during which time the metals become oxydized, and sulphurous acid gas is rapidly given off, whilst the ore is by constant stirring prevented from becoming agglutinated in masses. The temperature is now still further raised, and sulphurous acid is again given off, together with vapors of chloride of iron and hydrochloric acid. The hydrochloric acid generated at this stage of the operation is due to decomposition of the chloride of iron, by the action of oxygen and watery vapor. This last firing, which occupies about three quarters of an hour, is continued with constant stirring until a sample taken from the furnace ceases to evolve any odor of sulphurous acid, and has for its object the decomposition of the sea-salt by the metallic sulphates produced. During this process the ore increases considerably in volume, and assumes a deep brown color. When the roasting is terminated the charge is raked from the furnace to the floor of the establishment, from whence, after having been allowed to cool, it is removed for the purpose of being passed through a set of fine sieves, by which the finer powder is separated from the agglutinated lumps. These are broken down to a proper size, and after being mixed with a fresh quantity of sea-salt are again roasted in the usual way. The finer particles are, on the contrary, taken to a pair of heavy mill-stones, where they are reduced to the state of an impalpable powder. At the Halsbruecke works there are fourteen roasting-furnaces, and as many pair of granite mill-stones, which, together, are capable of preparing and

grinding about seventy tons of ore per week. The ore, after passing through the mill, which makes from one hundred to one hundred and twenty revolutions per minute, is sifted through a dressing apparatus, which renders it as impalpable as the finest flour.

The amalgamation of this prepared ore is performed in twenty wooden casks, arranged in four rows, and each turning on cast-iron axles, secured to the ends by means of bolts. These barrels, which are two feet ten inches in length, and two feet eight inches in internal diameter, are made of oak staves three and a half inches in thickness, and are further strengthened by iron hoops and blinders. On one of the ends of each tun is placed a toothed wheel, which works into another toothed wheel, mounted on an axle, which receives its motion directly from a water-wheel. Above each of the tuns so arranged is placed a wooden case, into which is thrown the prepared mineral, and which is furnished with a leathern hose, for the purpose of introducing the powdered ore

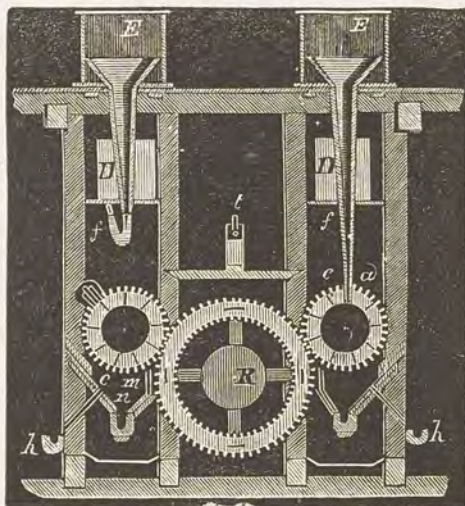


Fig. 89.

into the different barrels. With this view, each cask is furnished with a circular opening, and an iron or wooden pin, which is employed for running off, at the termination of the process, the argentiferous amalgam.

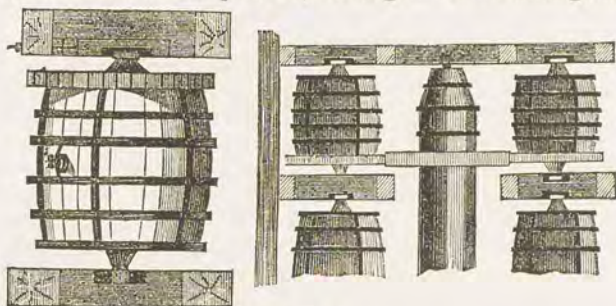


Fig. 40.

The basins, situated immediately above each tun, are of such a size as to exactly contain the amount of water necessary for one charge. Below the tuns, and a little above the surface of the ground, are placed triangular troughs, destined to receive the various elaborated products at the termination of the operation. At the commencement of the operation, 3 cwts. of water are run into each barrel from the reservoir, after which 10 cwts. of the finely ground and sifted ore are introduced through the hose. To this are added from 78 to 100 lbs. of wrought-iron, cut into fragments of about an inch square, and three eighths of an inch in thickness, and which, in proportion as they become dissolved by the action of the substances by which they are associated, are replaced by fresh pieces. The casks are now tightly closed by screw-stoppers, and as soon as they have all been charged, the apparatus is thrown into gear by the means of a screw, and the sliding block, which cause the tuns to rotate with a rapidity of from eighteen to twenty turns per minute. At the expiration of two hours the machinery is again stopped, and the tuns are opened for the purpose of examining the state of the metalliferous paste which they contain. If the charge is too firm, a little

water is added; but if, on the contrary, it is found to be too liquid, a small quantity of powdered ore is thrown in. When this has been attended to, 5 cwts. of mercury are poured into each cask, and the tuns, after being securely closed, are again thrown into gear, and kept constantly revolving for sixteen or eighteen hours, at the rate of from twenty to twenty-five turns per minute. During this time they are, however, twice examined, for the purpose of seeing whether the paste which they contain be of the proper consistence; for if it be too thick, the particles of mercury are not sufficiently brought into contact with the silver contained in the ore, and if too much water has been added, they remain at the bottom of the cask, and are not sufficiently mixed with the different constituents of the charge. In the first case it is necessary to add a small quantity of water, and, in the second, a little powdered ore. After the introduction of the mercury, the temperature of the casks becomes considerably raised by the chemical changes constantly going on within, so that, even in winter, it sometimes stands as high as one hundred and four degrees, Fahrenheit.

At the expiration of twenty hours the amalgamation of the silver is ordinarily complete, and the tuns are now entirely filled with water, and again made to turn two hours, with a velocity of only eight revolutions per minute. The amalgam is by this means separated from the slimy matters with which it was mixed, and collects in one mass at the bottom of the tuns. When this aggregation of the amalgam has been accomplished, the different casks are successively thrown out of gear, and are stopped with their apertures immediately over the spouts. A small peg in the bung is now removed, and the liquid amalgam flows out and is received in the triangular spout; the workman closely watches this period of the operation, and the moment any of the earthy matters begin to flow from the orifice, it is again tightly closed. The mercury is now run off through the iron tube, into the gutter, by which it is conducted into a receiver prepared for that purpose.

The casks are now turned with the apertures upward,

and as soon as the bungs have been removed, they are again brought back to their former position, and the muddy residuum is discharged into a spout, from which it flows into large reservoirs situated at a lower level. This residuary ore is found to be stripped of its silver to within about five and a half ounces to the ton, and is therefore often subjected to another amalgamation. The emptying and discharging of the casks occupies about two hours, and the whole process is therefore finished in something less than twenty-four hours. In fourteen days one hundred and sixty tons of mineral are treated in this establishment, every five tons of which require an expenditure of fifteen pounds of metallic iron, and two pounds twelve and three quarter ounces of mercury; so that every pound of metallic silver produced is obtained at an expense of 0.95 of an ounce of mercury.

During the first two hours that the casks are set in action, and before the introduction of the mercury, the sesquichloride of iron contained in the ore is decomposed by the metallic iron present, and converted into protochloride. If, instead of operating in the way described, the mercury were immediately introduced into the casks, it would, by reacting on the perchloride of iron, become partially converted into calomel, which, not becoming again reduced during the subsequent stages of the operation, would be productive of a considerable loss of this valuable metal. This inconvenience is, however, completely avoided by the action of the metallic iron, as the protochloride thus formed is entirely without action on metallic mercury. The chloride of silver contained in the roasted ore is held in solution with the chloride of sodium, and, becoming reduced to the metallic state by the constant agitation with the metallic iron, combines with the mercury to form a liquid amalgam. The chlorides of lead and copper are decomposed at the same time as the chlorides of silver, and enter into the composition of the amalgam produced.

When the residual earthy matters are drawn off from the casks, the pieces of metallic iron are retained by means of a grating, whilst the slimes, after being run into

proper receivers, are conducted into *pug-tubs*, where they are constantly kept stirred with a large quantity of water.

These tubs are furnished with openings at various distances from the bottom, by which the muddy water is successively drawn off, whilst a certain quantity of amalgam is found collected at the bottom of the vessel. This is collected at the close of the operation, and added to that obtained by tapping directly from the amalgamation-tubs, as before described.

The mercury and amalgam obtained from the casks is afterward filtered through close canvas bags by which the liquid quicksilver is separated from the pasty amalgam, which is retained by the closeness of the web, whilst the mercury passes through into reservoirs prepared for that purpose. The pasty amalgam which is retained in the bags consists of a mixture of six parts of mercury and one part of an alloy composed of about eighty per cent. of silver, and twenty of a mixture of copper, lead, bismuth, antimony, gold, nickel, zinc, and some other metals. This mixture is subsequently heated in a distillatory furnace, and is thus freed from the adhering mercury, whilst the non-volatile constituents of the alloy are obtained in the solid form.

Mr. Küstel remarks: "The amalgamation in barrels is not adapted to ore containing gold. Unroasted ore has been tried with chemicals unsuccessfully. The construction of the barrels does not differ much in the different works of Nevada Territory. They have a cylindrical shape, the diameter and depth being nearly equal. The staves are three or four inches thick. There are two sizes in use. The smallest, capable of receiving from one thousand to thirteen hundred pounds of ore, are thirty-two inches each way; the larger, receiving a ton of ore, measure from forty-four to forty-eight inches in the clear.

AMALGAMATION IN DR. VEATCH'S STEAM-TUBS.

The principle of this amalgamation, which is performed at the Central Works, (Virginia City,) is, in regard to

chemical procedure, the same as that of the barrel amalgamation. Chlorides and sulphates are decomposed by wrought-iron or copper plates. But while the barrels discharge the quicksilver after each amalgamation of a new charge, in order to save it from destruction by decomposition, the steam-tubs retain it for many charges, according to the richness of the ore. The quicksilver therefore takes an active part in decomposing the chlorides, forming calomel.

In this combination the quicksilver is always lost. The steam has no chemical action, but it may influence the amalgamation by its temperature. In regard to the mechanical part of amalgamation, these tubs differ entirely from the barrel arrangement. They are wooden tubs about four feet deep and four feet in diameter. The bottom is made of cast-iron with three circular openings for the reception of perforated plates, also of cast-iron, below which are the steam-chambers. The holes are very fine, about two inches apart. In the middle of the tub is an upright shaft, suspended on a box outside of the tub. There are three arms attached to it, each having three copper or iron plates hanging perpendicularly in concentric lines. The movable cover has an opening in connection with a flue by which the steam and some quicksilver are carried into cooling-tanks.

"The steam is forced through the perforated plates into the pulp, throwing the quicksilver in globules of all sizes constantly through the whole mass, causing a very perfect contact between the ore and the mercury. The iron plates—or if the ore is very copperous, copper plates—nine in number, have a circular motion, cut the ore with the edge, require very little power, and assist the motion of the pulp. The decomposition of chlorides goes on very rapidly in consequence of the heat and contact with the plates, which expose about thirty-six hundred square inches of surface to a mass of six or eight hundred pounds of ore. Under such circumstances the amalgamation may be effected in five hours, but as a matter of course the result depends entirely on a proper roasting."*

* Küstel.

AMALGAMATION IN PANS.

For details concerning the roasting of ores intended for amalgamation in pans, we must refer the reader to Mr. Küstel.

AMALGAMATION IN HEAPS. (Patio.)

This process, also known as the Mexican process, is so well described in Mr. Ward's work on Mexico, that we can not do better than to quote his description. The process, as practiced in Nevada, differs but little in its details. It is, however, but little employed.

The works described are those of the Valenciana mine at the Hacienda of Salgado.

"The ore, on being extracted from the mine, is placed in the hands of *Pepeñadores*, men and women, who break the larger pieces with hammers, and, after rejecting those in which no metallic particles are contained, divide the rest into three classes, called, in mining language, *Azogues*, and *Apolvillados buenos*, or *Ordinarios*. The *Azogues*, are the inferior ores, in which the matrix contains but a thin sprinkling of silver. As this increases, it becomes *Apolvillado ordinario*, and *Apolvillado bueno* when very rich. Sulphuret of silver, where it occurs but little intermixed with other substances, is designated as *Polvillos*; (probably because when reduced to *polvo*, dust, this dust is found to be richly impregnated with silver;) and *Molonques*, or *Petanques*, are the names given to the masses or crystallizations of pure silver, which are not unfrequently met with. The three last are too rich to be submitted to the ordinary process of amalgamation; but the *Azogues* and *Apolvillados* are transmitted in *costales* (miner's sacks,) weighing one hundred and fifty pounds each, to the Hacienda, where they are delivered to the Administrador, (overseer,) who gives a receipt for the amount. They are then submitted to the action of the morteros, (stamps,) one of which of eight stampers, (mazos,) is capable of reducing to powder ten cargass of ore, (each of three hundred and

fifty pounds,) in twenty-four hours. This powder not being thought sufficiently fine for the quicksilver to act upon it with proper effect, it is transferred from the

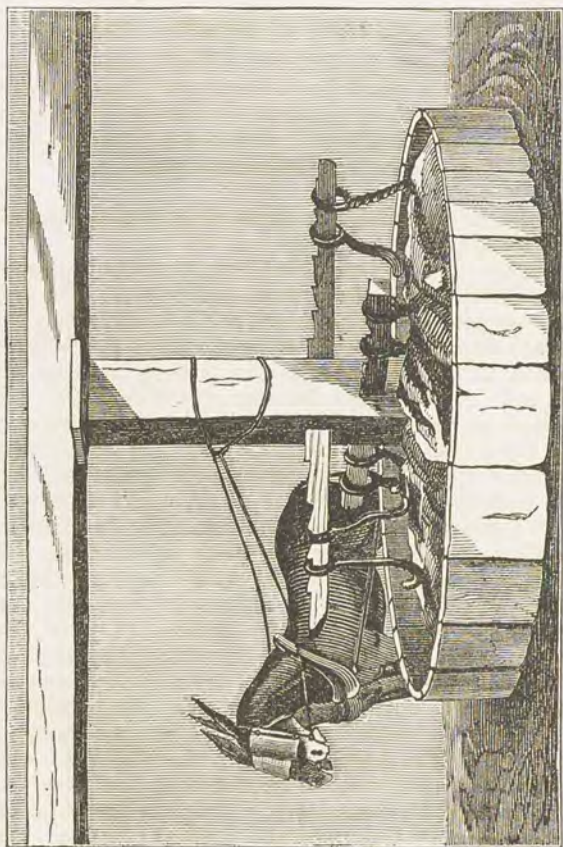


Fig. 41.—MEXICAN ARASTRA.

morteros to the arastras, (crushing-mills,) in which water is used. Each of these reduces to a fine, impal-

pable, metalliferous mud, six quintals of powder in twenty-four hours. At Guanajuata, where water-power can not be obtained, the *arastras* are worked by mules, which are kept constantly in motion at a slow pace and are changed every six hours. The grinding-stones as well as the sides and bottom of the mill itself, are composed of granite, four blocks of which revolve in each *arastra*, attached to crossbars of wood. This part of the operation is thought of great importance, for it is upon the perfection of the *Molienda*, (literally, the grinding,) that the loss of quicksilver is supposed in a great measure to depend. It is performed usually in a covered shed, or *Galera*, which, in a large hacienda like Salgado, from the number of *arastras* at work at the same time, is necessarily of considerable extent. From the *arastras* the ore is again removed to the *Patio*, (amalgamation court,) where it is disposed in *Tortas*, the size of which varies according to the dimensions of the patio, or the fancy of the *Administrador*, (overseer.) The number of *Montones*, (heaps,) contained in each *Torta*, is consequently uncertain; but the *monton* of Guanajuata consists of nine *cargas*, and two *arrobas*, or thirty-two quintals of ore; each *carga* containing fourteen *arrobas* of twenty-five pounds.

"The *monton* requires three *arrobas* of salt, (from Colima,) at one dollar, or nine reals, the *arropa*. This is added to the mass three days before any other ingredient.

"One *arropa* of ordinary magistral, (from Tepesalar, near Aguas Calientes,) or seven pounds of the very best quality, (Pepena.)

"Quicksilver in the proportion of three pounds for every marc of silver that the ores of the *monton* are supposed by the amalgamator to contain, and varying, consequently, according to the quality of the *monton*, which is determined by the eye.

"In the amalgamation of a large *Torta*, the same proportions are always observed; and the mass is repeatedly worked up by men and mules, (*repasadores*), in order to



Fig. 42.

promote the incorporation of the silver with the mercury, which it requires six weeks in winter, and one month in summer, to effect. When the amalgamator supposes the Torta to have *rendido*, that is, to have yielded all the silver that it contains, it is washed in large vats, (Tinas,) until the earthy particles are got rid of, when the amalgam, which remains at the bottom of the vat, is strained in leather bags until no more quicksilver can be separated from the silver by pressure. The remainder is cut into wedges, which are conveyed to the Quemadero, (burning-house,) and arranged in a circular pile round a copper plate called the Vaso, with a hole in the centre, and a receptacle for water beneath, care being taken to make the hollow left in the centre of the pile of amalgam correspond exactly with the hole in the Vaso below. The whole is then covered by a large iron bell, called Capella, or Capelina, which is strongly luted down; a wall of mud bricks is raised round it, and the intervening space filled with charcoal. The fire is kept up for twelve hours, in which time the quicksilver is sublimed, and afterwards condensed in the water, where it is subsequently collected. The

pure silver (*Plata quemada*) is then cut again into wedges, or melted down into bars, (containing one hundred and thirty-five marcs each,) in either of which shapes it may be transmitted to the mints.

"The loss of quicksilver at Salgado in the whole process, in the year 1825, amounted to nine ounces on each marc of silver; but this was thought to be an instance of very successful management, on the part of Mr. Belauzaran, as the proportion is, in other Haciendas, from ten to eleven ounces. He attributed the difference to the excellence of the *Molienda*, which he always caused to be continued until there was nothing harsh or gritty in the mass upon which the mercury was to act. He added, that the residue of the *Torta*, when washed, might contain some small portion of silver, but it had not been found that the quantity was sufficient to repay the cost of any further process, and it was consequently thrown away.

"The best of the *montones* which I saw at Salgado, were expected to produce fourteen marcs of silver; and those of an inferior quality, eight marcs. Two marcs and a half pay the costs of reduction, which amount to twenty dollars on the monton. Allowing as much more for raising the ore, and the share in the general expenses, there would remain a profit of three marcs, or twenty-five and a half dollars, on each monton of the poor *Azogue* ores; while on the richer *montones* it would amount to seventy-six and a half dollars, including the loss of quicksilver, which, in 1826, was worth six reals per pound.

"In other portions of Mexico, the process varies somewhat from the above, but the difference is not material."

Mr. Küstel remarks upon this process: "The *Patio* amalgamation, where wood and water are scarce, the ore suitable, the climate favorable, and labor cheap, is a very good process, and in many cases can not be replaced by a better one. The climate of Nevada Territory, at least in the summer, is very favorable for the *patio*; but several months of the winter time do not permit of this process, without having proper buildings, in which, by the aid of

steam and other arrangements, the required temperature is obtained, although the sunbeams and open air assist the process, independent of the temperature. On the other hand there are the disadvantages that the expenses of steam-power, horses, and men, are comparatively much heavier here in Nevada Territory, than for instance in Mexico or South-America."

"Ores containing gold can not be treated by patio unless that metal is extracted first in some other way.

"The ores most suitable for this purpose are, brittle-silver ore, polybasite, ruby silver, bromyrite, iodyrite, silver-glance, and chloride of silver.

"Silver combined with copper and antimony must be slightly roasted before being subjected to patio amalgamation.

"Argentiferous zinc-blend, pyrites, and some other combinations, can not be treated by patio without a perfect roasting. Gold ores and argentiferous lead ores are entirely excluded from this process."

MELTING PROCESS.

The smelting of silver ores, although carried on in several places in California and Nevada, is comparatively an expensive method and is never likely to be employed there advantageously, unless with ores containing a large amount of lead, or under some very peculiar circumstances. It seems unnecessary, therefore, to enter into a detailed description of the processes, which, however, may be found in Mr. Küstel's work.

Within the last twenty years, three new processes for the extraction of silver from ores, have been discovered and put into operation in Germany. Dr. R. H. Lamborn, who minutely described these processes in three letters to the *Mining Magazine* in the early part of 1861, and which descriptions may be found in Blake's *Silver Ores and Silver Mines* introduces the subject in the following extract, to which, for brevity's sake, we are forced to confine ourselves:

In point of priority of date, the plan of Hüttenmeister Augustin stands first. It was invented about the year

1845, and brought gradually into use at Gottesbelohnung Furnace, near Eisleben, in Prussia. It has given place to the plan next to be mentioned, but is now used in Saxony and in Hungary. The distinguishing peculiarity of this plan is to be found in the fact that the silver is converted by a chloridizing roasting into chloride [AgCl] and then dissolved away from its impurities by means of a hot concentrated solution of common salt. This plan may hence be appropriately called "Silver extraction with salt water."

The second method, which was also invented in the vicinity of Eisleben, by Hüttenmeister Ziervogel, another officer of the Mansfeld Mining and Smelting Company, consists essentially in converting the silver into a sulphate or vitriol, [$\text{AgO} \cdot \text{SO}_3$] by means of a very careful roasting of the sulphides of silver, copper, and iron in a draught of air, and then dissolving out this soluble salt with hot water. From the nature of the solvent, this plan may be known as "Silver extraction with warm water." It is now in use at the Gottesbelohnung furnace, and at Swansea in Wales.

The third and most recently invented method is that of Von Patera, "Metallurgic Chemist for all Austria." It is in use at Joachimsthal, and has, as far as I am aware, never yet been described with any degree of minuteness. It consists essentially in a transformation of the silver of the ores into a chloride, by roasting with common salt, and a subsequent dissolving out of the same with a solution of the hyposulphite of soda, [$\text{NaO} \cdot \text{S}_2\text{O}_3$] and precipitating the silver from this solution as a sulphide, by means of five-fold sulphide of sodium [Na S_5]. The process may hence be denominated "Silver extraction with hyposulphite of soda."

As we before remarked, our limited space forbids more extended details of the first and second methods, which are used, the former (Augustin's) at Freiberg, and the latter (Ziervogel's) at Mansfeld. A review of the difficulties in the application, and of the causes of loss of metals in each of the two methods, translated from the French of M. L. E. Rivot, will in conclusion be given :

"In Augustin's method, the essential point is the production of the chloride in the dry way. When the whole of the silver is changed to chloride, and the greater portion of all the other metals is left in the state of oxyds, the operation is a successful one, and there is no fear of losing any considerable portion of silver in the following operations. The chloride is easily soluble in a warm liquid containing twenty-two per cent of salt, and the lixiviation and precipitation only require care on the part of the workmen, and the attention of an intelligent superintendent.

"The difficulties of chloridizing in the dry way are very great, not only in the operation itself, but principally in the preceding operations of roasting and calcining. In changing all the silver present into sulphate by calcination, at a low temperature in the presence of an excess of air, sulphates of all the other metals are formed. These may be almost completely decomposed by a prolonged calcination, but it is not possible to raise the temperature high enough to attain the desired result without decomposing the sulphate of silver. The sulphates of iron and copper may be almost wholly decomposed; but those of lead, zinc, cobalt and nickel, remain almost unchanged. The success of the *calcination* thus depends, in part, upon the care taken by the workmen, but chiefly upon the chemical composition of the matt submitted to treatment.

"The transformation of the sulphates into chlorides should be rapidly made, at a low temperature, as the chloride of silver and the chlorides of the other metals are volatile. The chlorides of iron and of zinc are the most volatile, and produce the greater part of the loss in silver. By carefully conducting the roasting and calcination, the quantity of chloride of iron may be much diminished, but it is not so with the chloride of zinc. It is therefore essential to avoid submitting matts containing zinc to the process. Only a portion of the volatilized chlorides is collected in the condensing-chambers above.

"With matts containing arsenic and antimony, the

difficulties are much greater. Roasting at a low temperature with an excess of air, changes nearly all the arsenic and antimony into arseniates and antimonates which can not be decomposed by calcination, and must be changed into chlorides. A longer continued and greater heat is required in chloridizing; and the formation of a large quantity of chloride of iron can not be avoided. The loss of silver by volatilization of the chlorides, is much greater than with the pure matts.

"In Ziervogel's method, applied to very pure matts, the chief difficulty is, to so modify the temperature, during calcination, as not to destroy the solubility of the sulphate of silver in water. For this part of the elaboration of the matts, the method is much superior to Augustin's, since it avoids the difficulties and the causes of loss in chloridizing.

"The solution of the sulphate of silver in water is always very slow and difficult, and it can not be known when it is complete. It is necessary to assay the residues for silver, and to roast over again those that are too rich. This richness of the residues in silver entails a loss which is nearly equivalent to the loss by volatilization of the chlorides in Augustin's method. There can not be a great difference between the proportion of silver taken from the matts by the two methods, and it can only be presumed, if the operations by each are conducted with all the necessary precautions, that the loss of silver is a little the least by Ziervogel's. The expenses, also, being less, this method is, without doubt, the most advantageous for very pure matts.

"When the matts contain a notable proportion of arsenic and antimony, there is always a certain quantity of arseniate and antimoniate of silver formed, which are insoluble in water, even when recourse is had to mixing lignite with the charges, or the action of steam thrown in upon the sole of the furnace, as at Freiberg.

"All the silver so combined is necessarily lost; while in Augustin's method, a portion of the chloride of silver formed from the decomposition of the arseniate and anti-

moniate during roasting, may be expected to remain in that state during the process of lixiviation.

"It can not, therefore, be said that with matts containing arsenic and antimony, Ziervogel's method yields more silver than Augustin's.

"Sufficient comparative experiments upon this subject have not yet been made, and from those that have, it can not yet be decided which of the two methods is the more advantageous for extracting the silver from the impure matts. It is only well demonstrated that the loss in silver is, in all cases, greatly increased by the presence of arsenic and antimony.

"The cupriferous residues are nearly equally charged with arsenic and antimony, but those left by Ziervogel's process contain basic sulphates which are very useful in smelting for black copper. By Augustin's method, there is always a notable loss of copper, and the residues are without sulphur."

DESCRIPTIONS OF FURNACES, MACHINES, ETC.

IN the following pages figures and descriptions will be given of the most improved machines and apparatus for the crushing, reduction, and mining of gold and silver ores, including some to which a brief reference only has before been made.

Figs. 43 and 44 are a ground-plan and section of a fur-

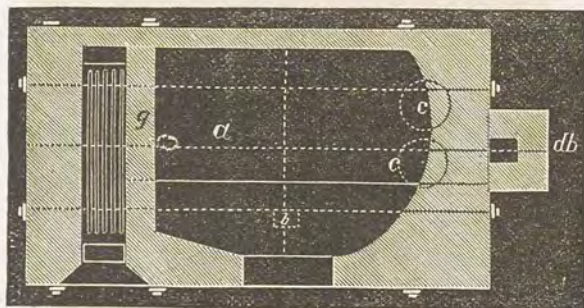


Fig. 43.

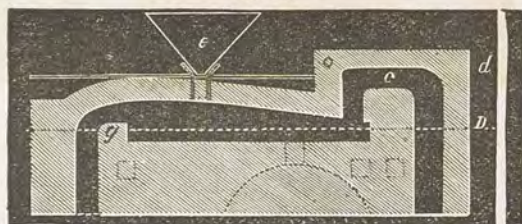


Fig. 44.

nace fitted for the economical roasting of silver ores. The hearth-bottom, *a*, is made of the hardest bricks, laid edgewise, as close together as possible. The ore is introduced by the funnel, *e*, Fig. 44, and after roasting is discharged through the opening, *b*, Fig. 43, in the floor of the furnace. The distance between the arch and bottom near the bridge, *g*, is 21 inches, but near the flue, *c*, it is only eight inches. The flue, *c*, is led, either directly or through dust-chambers, into a chimney, which for a single furnace should be twenty-five to thirty feet high, and from sixteen to eighteen inches square. The bridge, *g*, which is the part most exposed to injury, both from the direct action of the fire and from the hoes used for stirring, should be of some kind of sandstone, granite, or conglomerate which does not crack when heated.

Fig. 45 represents a mechanical roasting furnace, described by Mr. Küstel in his work, in which the hearth

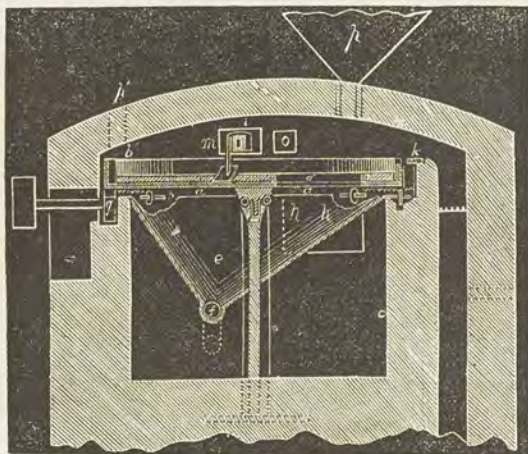
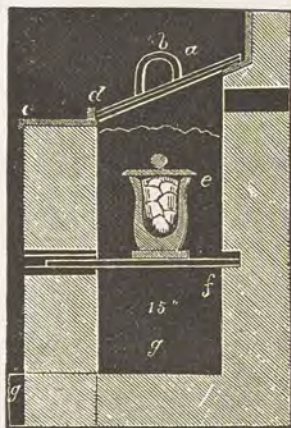


Fig. 45.

is made to rotate, so as to successively present the different portions of the ore to the flame. The iron hearth-frame, *a a*, is twelve feet in diameter, and has sides ten inches high, which are lined with fire-tiles, *b*, and the

bottom, four inches thick, is formed of fire-bricks. The ore is discharged through the opening, *d*, 39 inches long and four wide, with a hinged iron door, into the funnel, *e*, which carries it outside the furnace. The cog-wheels, by which the hearth is turned, and the rollers and balls on which it rests, are shown at *g* and *h*. The ore is introduced by the funnel, *p*, and is continually stirred by the iron stirrers, *n*, which are cooled by means of a current of cold water.

Figure 46 shows a good form of furnace for operations with a crucible. It is fifteen inches square, lined



Figs 46.

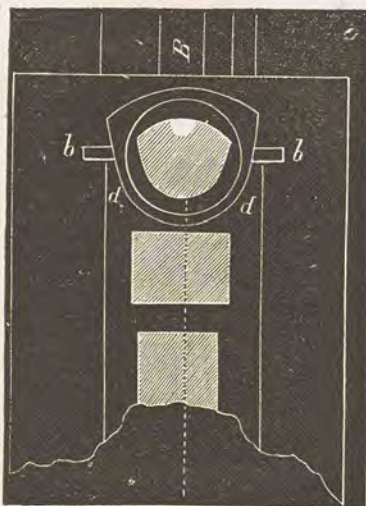


Fig 47.

with fire-brick. It has sliding-doors, *a*, at the top. The crucible stands on a piece of fire-brick on the grate, *f*, which consists of movable iron rods.

Figs. 47 and 48 represent a furnace used for "retorting," or distilling off the quicksilver from the amalgam of gold and silver obtained in various operations. Fig.

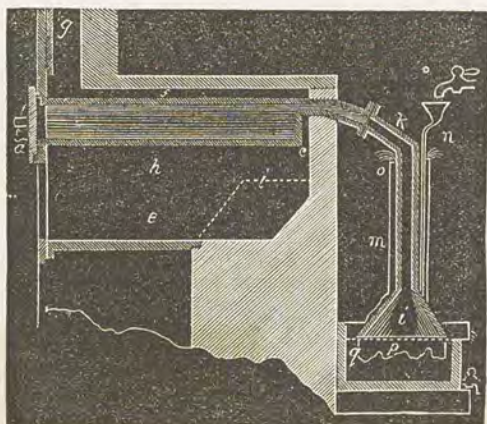


Fig. 48.

47 is a front view ; the cover, *a*, Fig. 48, of the retort being removed. The retort is made of cast-iron, four feet long, eleven inches wide, and nine inches high. The retort has two wings, *b*, Fig. 47, on which it rests on the masonry so as to leave three inches clear on each side. The flame is thus compelled to traverse the whole surface of the retort both above and below. The fireplace has grates two feet long, and may be three feet long or somewhat shorter according to the kind of fuel. The condensing pipe, *k*, is terminated by a funnel, *l*. A sheet-iron pipe, *m*, rests on the funnel, and a continual stream of cold water is kept flowing around the pipe. The funnel is wrapped around with cloth, *p*, which reaches into the water. The water in the vessel, *a*, should be kept at a level about half an inch below the funnel.

Figs. 49, 50, and 51 represent a furnace suited for the smelting of silver ores, an operation which, however, will probably, as remarked on page 144 rarely prove profitable. The cast-iron pan, *a a*, 37 inches in diameter and 15 inches deep, which serves for the reception of the fire-proof material forming the hearth, is supported on some fire-bricks, so as to allow a current of air to pass around

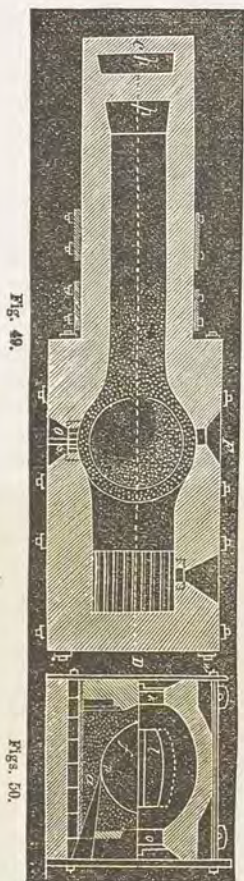


Fig. 49.

Figs. 50.

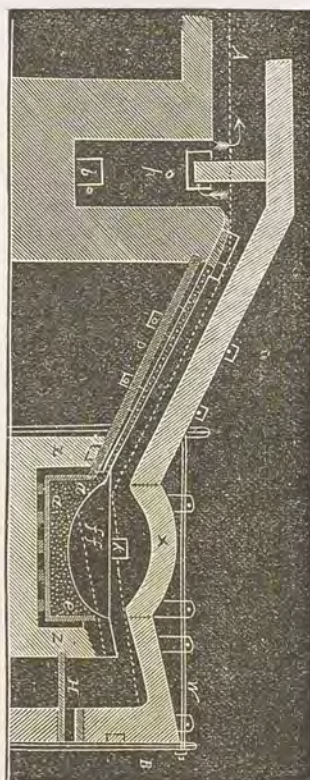


Fig. 51.

the bottom and sides in order to cool it. The fire-proof material, composed of old fire-brick, ground and mixed with one third its bulk of good clay, or of three parts of pure white quartz with one of clay, is beaten with iron rammers, so as to rise six inches above the edge of the pan,

and is then cut into the proper shape with a curved tool. The flue-plate, *d*, is first lined with a row of fire-brick, and upon that a layer of fire-proof material is beaten carefully down. The ore is introduced at the feed-door, *i*, whence the melting mass runs down to the hearth, *f f*. The slag is run off by the channel, *o*, and the metal and matt are discharged by the tap-hole shown in Fig. 86, passing through the hearth-mass. The ore carried off by the draft is collected in the dust-chamber, *p*, which has openings in the side by which it may be cleared. The chimney should be 40 or 50 feet high, 18 or 20 inches square inside, and lined with fire-bricks. The fire-place, *H*, is calculated for coal. This furnace also serves very well for refining silver or melting retorted amalgam.

Figs. 52 and 53 represent a cupellation furnace. This operation, briefly alluded to under the head of blow-pipe operations, is applied to lead containing silver, and consists essentially of exposing the melted lead to a cur-

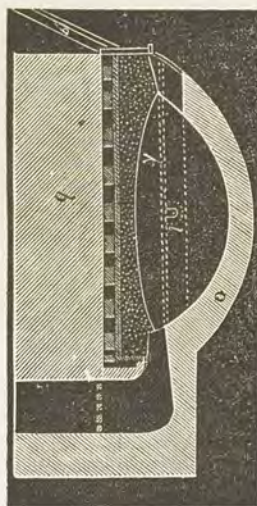


Fig. 52.

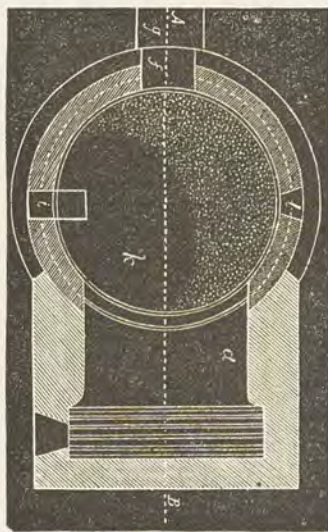


Fig. 53.



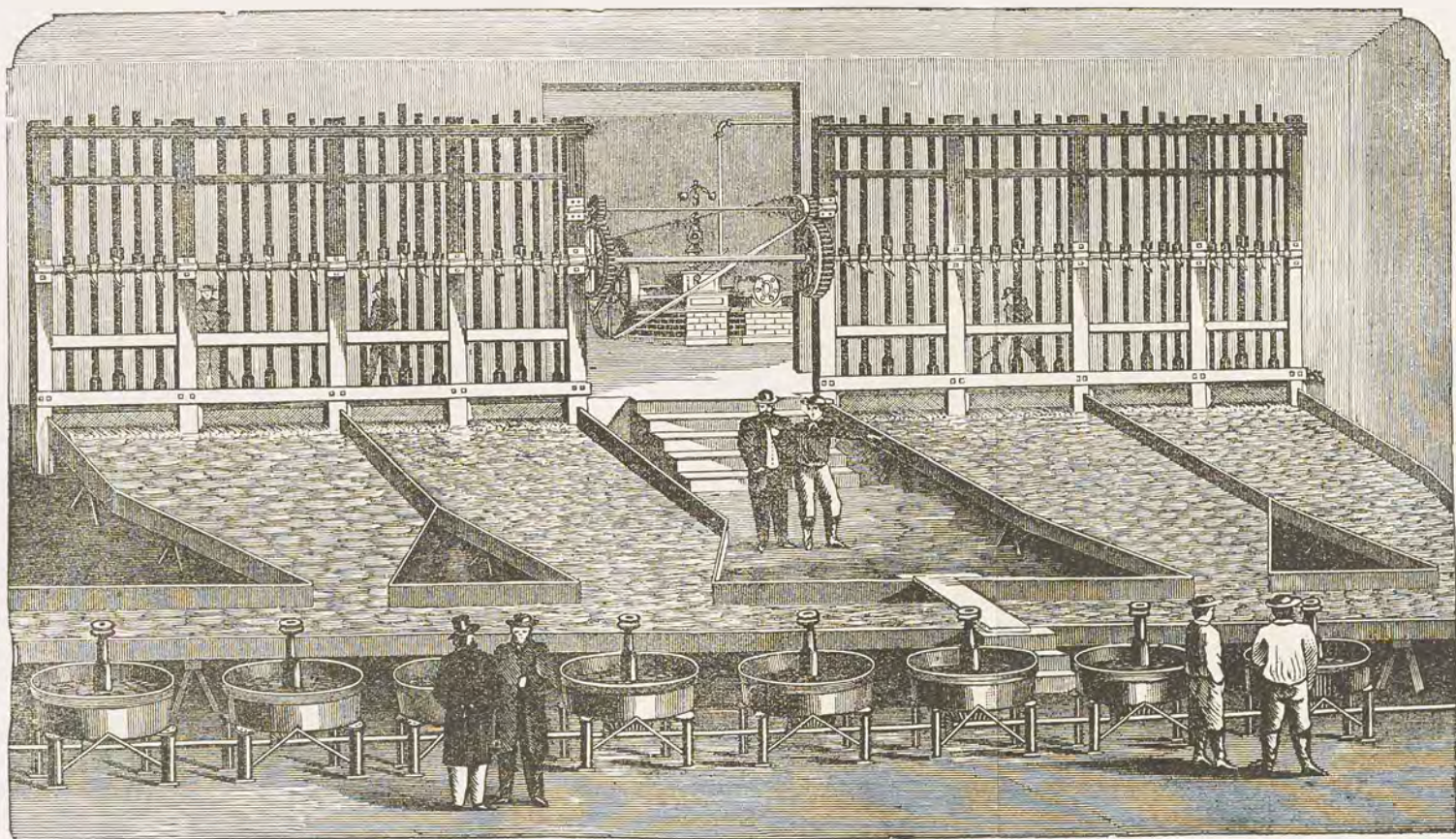


FIG. 26.—STAMP-BATTERY—WET CRUSHING, WITH HEPBURN & PETERSON'S PANS.

rent of air, by which it is converted into oxyd of lead or litharge, which is partly absorbed by the porous support or cupel, and in part runs off by grooves cut in the side of the cupel. The other base metals, such as copper, contained in the alloy, are also converted into oxyds, which are dissolved in and carried off by the litharge, and at the end of the operation the silver (and gold, if any is present) remains in a brilliant mass of almost perfect purity. This process is applied not only to lead from ores containing silver, but to other mixtures of metals resulting from smelting operations, containing a considerable amount of silver, and these are previously melted with several times their weight of lead. The furnace is of very simple construction. The iron pan is four feet in diameter, with a throat, *f*, ten inches long and twelve wide for the escape of the litharge, which falls upon the cast-iron plate, *g*. The pan is filled with bone-ashes, wood-ashes, marl, or a composition of pulverized limestone and clay well beaten together. The blast is introduced at *l*. The bars of lead are introduced at *i*, where a fire-tile is placed inclining slightly inward.

Most of the figures of furnaces here described, as well as those of pans, etc., in the chapter on the metallurgy of silver, are taken from Küstel.

In Fig. 26 a general view is given of the operation of wet-crushing. In the background are the stamps, raised by cams. The ore escapes through the wire screens seen at the bottom of the batteries of stamps into the sluice-boxes seen in the middle of the engraving. In front is a row of Hepburn & Peterson's pans.

Fig. 54 represents Beath's Amalgamator.

DESCRIPTION OF PARTS AND LETTERS.

A—Driving-shaft.

B—Cylinder.

C C—Levers to stuffing-boxes.

D—Lever for pressing upper shoes upon the cylinders.

E E—Upper shoes or dies.

F—Inside of cylinder.

G—Concave bottom of casing.

II—Outside casing.

One hundred and forty revolutions per minute—minimum speed.

INSTRUCTIONS FOR USING BEATH'S AMALGAMATOR AND SEPARATOR.

Two of the amalgamators being in operation with one separator, each amalgamator is to be charged with eight hundred or one thousand pounds of ore as it is collected from the batteries; at the same time add sufficient water to keep it at a thick, pulpy consistency; you then add from ten to fifty pounds of quicksilver, according to the character and richness of the ore. The machines are kept in operation until the reduction and amalgamation are complete, which time will vary from two to four hours, according to the character of the ore being reduced.

After the ore is sufficiently reduced and amalgamated, the pulp is discharged into the separator, and the machine is immediately re-charged without stopping.

After the pulp is received by the separator, it is to be thinned with water to a consistency that will allow the quicksilver and amalgam to precipitate and still retain sufficient body to keep the coarser particles of the pulp suspended in the water with the slum.

The inventor, a resident of San Francisco, in announcing his invention to the public, says:

"Special attention is called to the following distinctive features, which form the substance of my patent, issued by the United States Patent Office, December twentieth, 1864:

"The reducing is done on the *top and sides* of a revolving horizontal cylinder, inclosed in a casing filled with pulverized ore, so as to cover the cylinder, while the quicksilver occupies the concave bottom of the casing *beneath the cylinder*. By the velocity of the cylinder the diluted ore is drawn in through central openings in its ends, and ejected through narrow openings in its periphery upon the quicksilver, but not with sufficient force to raise it to the level of the dies.

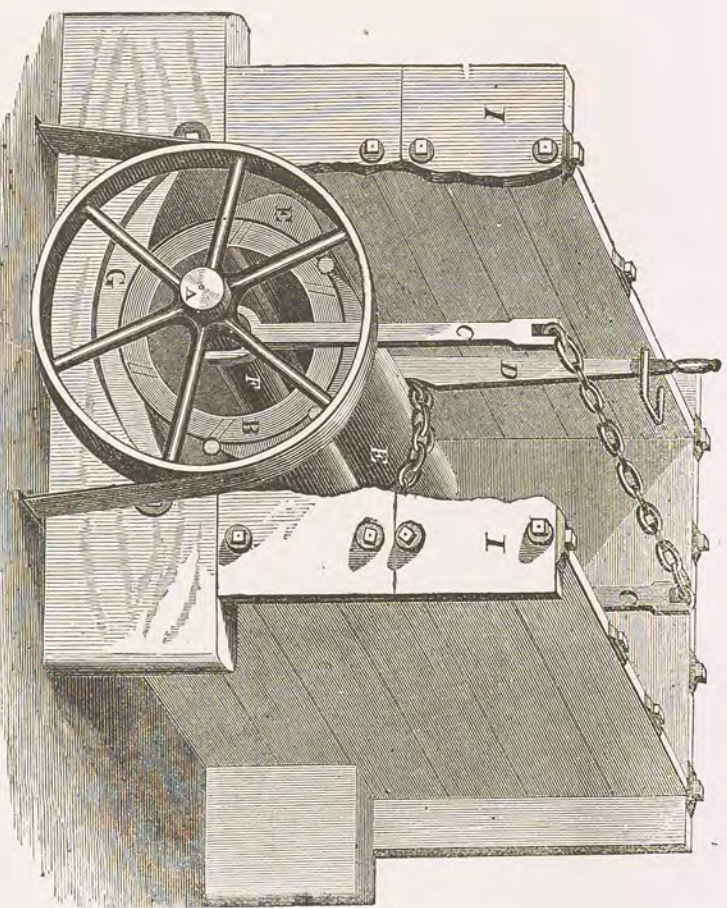


Fig. 54. Beath's Reducer and Amalgamator



"The extraordinary rapidity with which ore is reduced to an impalpable slum in this machine, is due to the method of hanging the dies, so as to adjust themselves as they wear, always remaining open in front for the reception of the coarser particles of ore, and constantly reducing them as they pass back by the surfaces converging to a close contact at the back of the dies. Those who have had experience in reducing ores with the machines in use will appreciate this improvement.

"Among other considerations is a comparatively high speed obtained, with great economy of power—the grinding surface only being exposed; also, a degree of heat sufficient for amalgamation obtained by its own action; and it is cleaned up with the greatest ease, without removing any portion of the machine.

MESSRS. STORER AND WHELPLEY'S REDUCTION WORKS.

The Boston Milling and Manufacturing Company have introduced machinery for the pulverization of gold and silver ores, in which mechanical principles are applied that have never before been employed for such a purpose.

The ores are broken, in the first instance, by the rapid movement of a circular iron table—a mass of metal three and a half feet in diameter, weighing eight hundred pounds, making ten hundred and twenty-five turns per minute.

The table itself forms the bottom of a cast-iron tub, eighteen inches in depth, of which the sides are grated, or perforated with small openings. The entire structure, except the upright shaft upon which the table revolves, is of cast-iron, the wearing parts being of what is called "white" iron, or Franklinite, which is so hard that it cuts glass. The upper surface of the whirling-table, or bottom of the tub, *E*, is furnished near its circumference with several blocks, *H*, called cutting or splintering-blocks, also of Franklinite. Any thing hard or brittle thrown into the tub is instantaneously splintered into

small fragments by concussion upon the edges of these blocks.

The wear or destruction of the machine is confined to the exposed faces and edges, which are made prominent

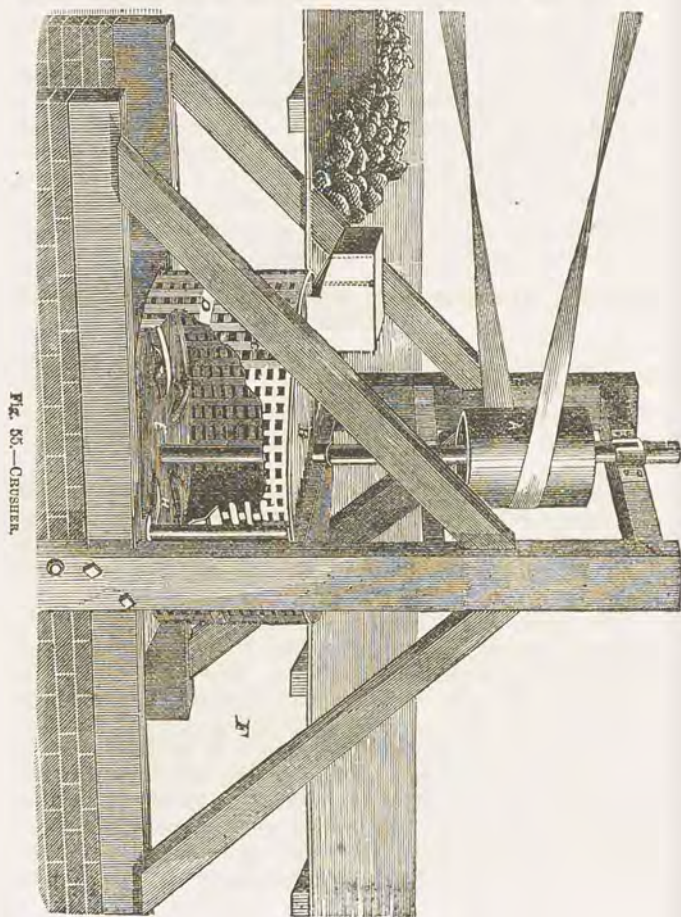
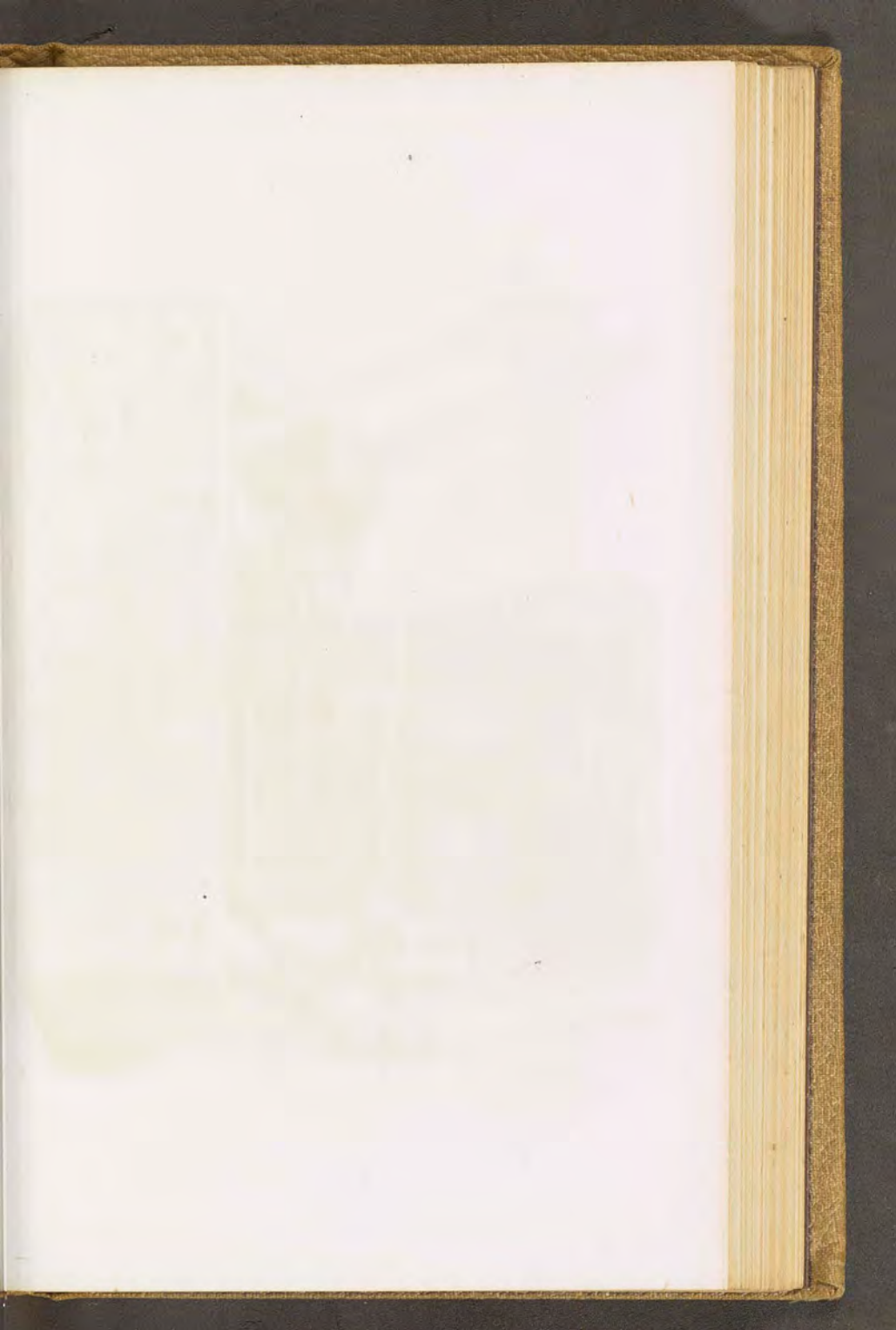
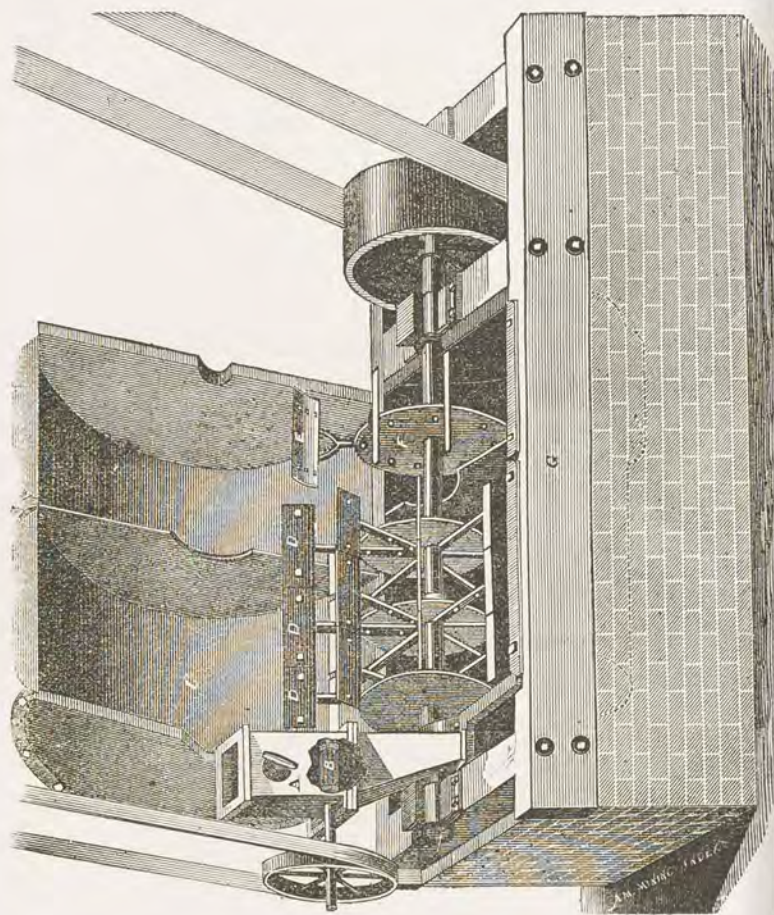


Fig. 85.—CRUSHER.





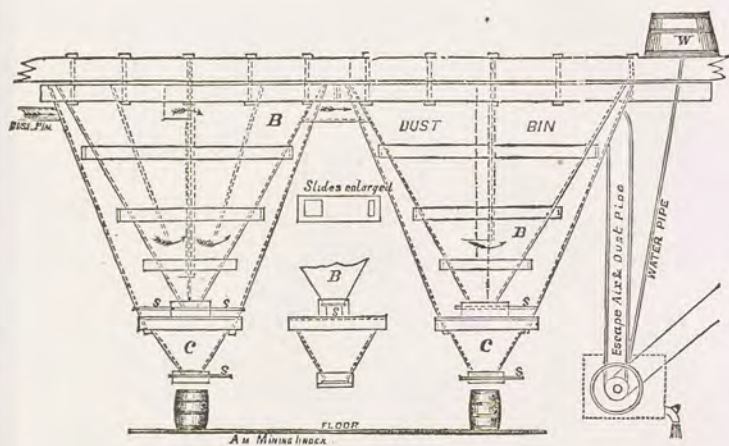
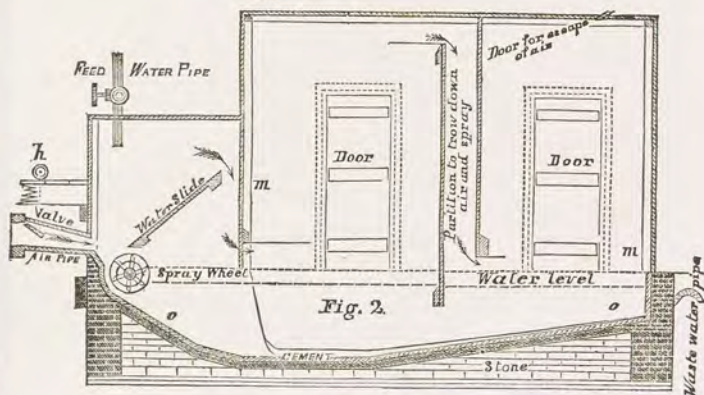


Fig. 1.



Figs. 57 and 58.



for the purpose of splintering and cutting; and to the lower portion of the perforated sides of the tub, through which the broken stone escapes.

These wearing parts are made replaceable, in sections.

The whirling-table, revolving freely upon a steel pivot resting upon a cup of oil, moves with the least possible friction, and will make three thousand revolutions by its own momentum, when left to itself.

It serves, in fact, as a powerful fly or balance-wheel, to regulate the other machinery. As soon as the material to be broken is thrown into the crusher, it shows a consumption of steam-power. The rate of resistance is about *one and a half horse-power per hour* for each ton of quartz; five tons per hour require, again, about seven and a half horse-power; ten tons, fifteen horse-power, etc.

To obtain these results, however, the velocity of the whirling-table *must always exceed one thousand revolutions per minute*—say between one thousand and one thousand and fifty; that is to say, the extreme end of the cutters must move with a velocity exceeding ten thousand feet per minute.

It is found in practice that one hour's work of the table will keep one pulverizer supplied for six or eight hours. The weight of the table, with its case, shaft, frame, cutters, etc., complete, and packed ready for transportation, is about three thousand six hundred pounds.

The best method of using the machine is not to feed in more material than will exhaust ten or fifteen horse-power.

The size of the particles thrown out by the table is gauged by the size of the perforations in the sides of the tub. If these are half an inch in diameter, the yield of quartz will be like small gravel. If the exit-holes are much smaller than half an inch, the yield will be like coarse sand mixed with gravel, etc.

The whirling-table is more rapid in its action than any other machinery for cutting or breaking. *It is capable of reducing more than two hundred tons of ordinary*

quartz, in pieces from three or four inches in diameter, to coarse gravel size, in twenty-four hours.

The table is furnished with different cutters, according to the work it has to perform. The work, in all cases, is faster and better done when the cutters are sharp.

When the whirling-table is used for the reduction of bones, plaster, coal, and other substances—soft and friable when compared with quartz—the tub is lined with boiler-plate, perforated with holes from half an inch to an inch and a half in diameter.

When quartz is to be reduced, this lining is removed, and gratings of hard iron, or Franklinite, with smaller perforations, are substituted.

Heavy masses of stone, weighing twenty or thirty pounds, may be thrown upon the table when it is in motion, without danger of breaking it; but for work of this class the sides of the tub must be of extraordinary strength. Nor is it a profitable application of power; the best work being done by the table upon pieces less than four inches in diameter, or about the proper size for stamps. Large stones must be broken by hand.

There is no use of air in the action of the whirling-table. The broken fragments are swept through the holes or grating of the tub the instant they are produced, by the immediate action of the advancing faces of the cutting-blades. Thus it happens that no part of the work of reduction is performed by the sides of the tub, but solely by the blades.

If any part of the table or its case is broken, as it might be by throwing in heavy masses of solid iron ore or large pieces of iron—it is the gratings of the sides, or the edges of the hammers, and no other part of the machine. The broken parts are easily replaceable.

The table is made strong enough to bear fifteen hundred revolutions per minute, without rupture; but any speed above ten hundred and twenty-five turns per minute is wasteful of steam-power, and does not much increase the yield.

The Company do not intend their machines to be used

at a speed above twelve hundred revolutions per minute, and they *must not* exceed that velocity.

The blocks of metal used as breakers, bolted upon the outer edge and upper face of the table, must be masses of solid white iron or Franklinite. The hardest metal is, of course, the best for this purpose. There are some minerals, especially those which contain deposited oxyds and silicates of iron in large quantity, that will wear out a set of ordinary cast-iron table-blocks, in the reduction of twenty or thirty tons of the stone to coarse gravel. The same blades that will only reduce twenty tons of these emery-like minerals—making the cost equal to one dollar a ton for breaking—will reduce one hundred and fifty or two hundred tons of ordinary quartz; and of marble, limestone, barytes, sandstone, pyrites of iron and gold, average silver ores, etc., a still larger quantity. Anthracite coal, though a sharp, cutting mineral, hardly wears the blocks. For the severest labor, say five tons an hour, of rare silicate of iron, approaching emery in hardness, none but the Franklinite iron *chills* should be used, *if they are attainable*. If not, use blades of the most flinty white (sulphury) iron; or, if that can not be had, make chills in which the hardening process penetrates a full inch and a half into the top and sides of the block. The best gray iron is the best for chills like these.

In general, the higher the velocity of the whirling-table, *the less it wears, according to the amount of work done*.

If a table delivers only two tons an hour, gravel size, of "emery-like," hard iron ore, or five tons of quartz in the same time, (which is an approximate difference,) having a velocity of eight hundred revolutions per minute, the same machine will deliver nearly *twice* the quantity of the same minerals, in finer and more even grain, with an increase of speed up to ten hundred and fifty turns a minute—but the wear of the splintering-blocks and screens will be no greater, but less in proportion, than with a low velocity.

The whirling-table is intended to reduce ores, from a

diameter of from three to six inches, to the condition of mixed sand and small gravel, chiefly the latter, with a very small percentage of dust. By making the holes very small in the sides of its case, the whirling-table may be made to yield only fine sand and dust; but this machine, like all other crushers, will not work economically as a pulverizer, and it is, therefore, useless to carry the reduction below the size of gravel. The reduction of ores to the condition of floating dust is accomplished best by a mill which can be used for no other purpose.

This machine is constructed solely for the pulverization or reduction to dust of sand, gravel, or the small work of stamping-machines, and can not be used itself as a crusher or breaker. It consists of four parts or elements, all of which are necessary to its use. The *first* is an automatic feeding-mill, which furnishes a regular and constant supply of the material to be pulverized.

The *second* element is an iron drum or cylinder, containing an air-wheel, which converts the sand or gravel into dust by the action of rotary currents of air, created by the wheel. No air enters or escapes from this cylinder *unless by the aid of other machinery*. The material can be retained in the cylinder until it is completely reduced.

The *third* element is a fan-blower—placed near, or at a considerable distance from the pulverizing cylinder—by which the dust is drawn from the latter as fast as it is generated.

The fine sand, auriferous earth, or other material, is pulverized in the first cylinder by the action of currents of air, generated by the air-wheel; the dust is thence drawn out, in company with air, by the exhaustive force of the fan-blower.

The *fourth* element is a chamber, or series of chambers, to receive and collect the dust generated by the pulverizer. The dust-chambers are variously constructed, to suit the nature of the material which is to be reduced, and are adapted either for dry or wet grinding, as may be required.

If the chambers or dust-rooms are properly construct-

ed, according to the plans furnished by the company, there is no loss by leakage or waste of material.

The pressure of air upon the interior of the dust-rooms is oviated by a simple and effectual contrivance, which also saves a small percentage of dust, which would otherwise escape with the exhaust or spent air of the chambers, after the main body is deposited.

A single pulverizer, applied to the reduction of gold ores, accomplishes, with a smaller consumption of steam or water-power, the work of twenty stamps. But the *quality* of the work produced is beyond all comparison finer—at least one fourth of the quartz-dust of the pulverizer being in fineness, when compared with average stamp-work, nearly as four million to one, and the rest nearly in proportion.

No other machinery, at present known, will produce this result, either as to quantity or quality.

But, further, if certain valves in the machine are thrown open, and the steam-power proportionately increased, then *one pulverizer does the work of thirty stamps.*

The interior construction of the pulverizer is set forth in Fig. 56, and differs entirely from other machinery employed for similar purposes.

The second air-wheel, as already stated, is a common fan-blower; being a cylindrical box containing the usual air paddle-wheel, of which the shaft passes through the center of axis of the box. The air-wheel is furnished with paddles, which give a rapid rotatory motion to the air in the box, throwing it out through an opening at the bottom.

A current of air is drawn or forced through the first or pulverizing cylinder by the action of the fan. No air enters or escapes from the first cylinder except from this cause.

If a common fan-blower is made of great strength, with a cast-iron case, and the paddles of thick plates of metal, constituting hammers, it may be used as a crushing-mill. The material being fed in at the side air-hole, will fall toward the circumference and be broken into a

mixture of gravel, sand, and dust, from ten to twenty per cent being fine or "floated." The air rushing out constantly (as in all fan-blowers) at the peripheral opening or exhaust, will carry with it a mixture of dust, sand, and gravel, generated by the action of the hammers. But it is impossible, with this arrangement, to prevent the escape of sand and gravel. The mass of matter is driven out pell-mell by the current of air escaping at the exhaust-pipe.

In order to produce dust or flour *alone* from sand or gravel, it is necessary, *first*, that the entire charge or load should *remain in the mill*, subject to the pulverizing action; and, *second*, that the external force of air applied to draw out the dust, may, when required, be prevented from drawing out the sand and gravel in company with it. *There must be a combined action of separation and exhaustion, to which the fan-crusher is inadequate.*

It is important that the material to be pulverized should be broken and crushed to the condition of gravel before passing into the pulverizer. The reduction of this gravel to sand or dust is not accomplished, as some have supposed, by the *friction* of the paddles, or the blows given by their faces. The paddles themselves act as fans, producing whirls or vortices of air, by which the particles of the material are put in rapid revolution; *and it is the friction of the particles, one against the other, that furnishes the dust*; under the microscope they are found not to have cutting edges, but to be rounded like pebbles, however small.

The quantity of dust furnished by a pulverizer will depend upon the degree of agitation and movement that can be communicated to the air and material in the pulverizing cylinder, and the quantity of material which can be kept in movement at once.

It is found that with a pressure of only fifteen horsepower, (equal to forty-seven and a half pounds moving with a velocity of ten thousand seven hundred feet,) more than fifteen hundred pounds of pulverized quartz can be delivered every hour, of which one third will have the character of fine dust.

The remainder will be much finer than the best stamp-work. There is no other machinery known that will give results approaching these.

It is possible to increase the quantity delivered, by increasing the constant quantity in the mill; but the gain does not compensate for the increased expenditure of steam-power. The air-wheel labors in a mass too heavy to be pulverized by the mere agitation of air.

It will now be understood that the *quality* of the work of the air-wheel is determined by its velocity. At a speed *less* than one thousand revolutions a minute, the quantity of fine dust produced diminishes rapidly. At velocities much exceeding one thousand revolutions per minute, the consumption of steam becomes excessive in proportion to the result.

The proper velocity for economical production is about one thousand and twenty-five turns in a minute. This will require fifteen horse power to produce fifteen hundred pounds of quartz-powder, four fifths of which should pass through a sieve of one hundred threads to the linear inch.

By allowing a freer current of air this quantity may be increased, but a certain portion of it will have the character of sand or fine grit, though *none* of it will be as coarse as the best stamp-work.

A very fair estimate of production allows one hundred pounds per hour of average dust to the horse-power. Assuming this to be the true standard of production, the ratio is not altered by increasing the size of the machinery, but depends mainly upon the quantity of fuel consumed by the engine, if this latter be large and of good construction. The mills at present manufactured by the Company are eighteen inches in breadth and forty-two in internal diameter. They have twenty-four paddles, of Franklinite, or hard white iron, six inches long by three and a half in breadth.

THE AUXILIARY FAN, FOR DRY GRINDING.

Too much can not be said of the importance of the auxiliary fan. It is placed at the extreme end of the

dust-chambers, and by drawing *as large a body of air out of the chambers as the first blower throws into them*, it entirely prevents leakage and loss of fine material in the crevices of the chambers.

The second use of the auxiliary fan-blower is to furnish a fine spray in dry grinding, by which a small residuary percentage is saved that would otherwise escape into the atmosphere.

The fan-blowers, adapted to spray-chambers, are furnished with a system of arms or dashers which effectually distribute or break up the water before it enters the fan-case. This is to prevent waste of power, which would ensue if the blades of the fan were allowed to dip into the surface of the water.

Care must be taken not to load the auxiliary blower with too much water, as it will cause a waste of power. If the spray-chamber is found not to do its work thoroughly, it must be extended, and the number of partitions increased, and more water allowed to rise upon the dashers.

DUST-CHAMBERS.

The Company's mills are connected with several kinds of dust-chambers.

The simplest kind is a small chamber with two or three partitions set over a pool or tank of water. The air and dust are blown directly into the spray-box or wheel-house, which is furnished with a simple paddle-wheel, so arranged as to create two columns of spray. In this kind of chamber the air, after being washed clean of its dust, escapes at the extremity of the chamber by a trap-door or valve, regulated by a cord. By raising or lowering this trap, more or less air is suffered to pass through the pulverizer. The fan-valve in front of the spray-wheel must be used in conjunction with the trap. The effect of the two is different. This kind of chamber should not be used when ores are to be roasted, as the wet dust will require to be dried in a furnace. For all ores that require burning, the chambers for dry grinding must be used.

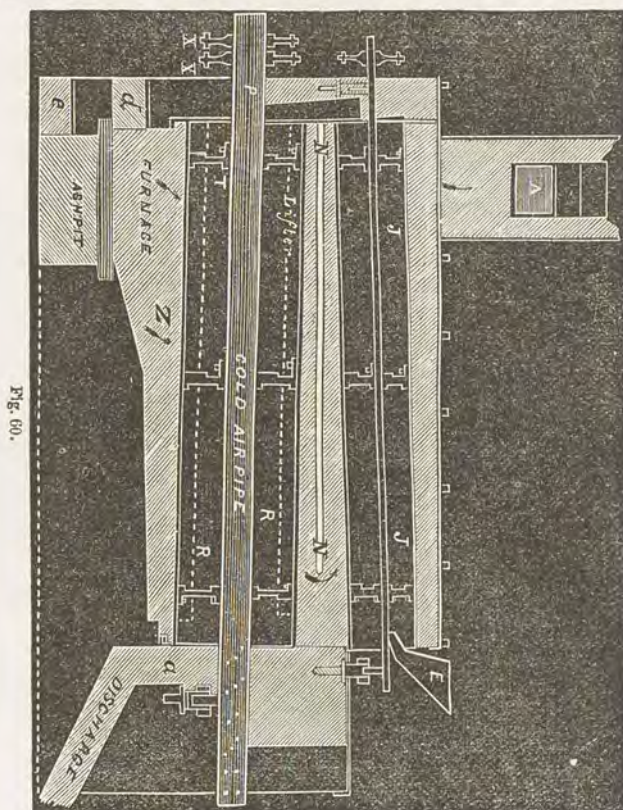
The second variety of dust-chamber is a series of rooms or apartments, which may be of any convenient size, to be used for dry grinding. *The larger the better.* Forty feet long, by ten wide and high, divided by double partitions, as represented, into four chambers, is a convenient size. The partitions are made double, with an air-space of from six to eighteen inches. The air-space gives the air a downward direction. The coarser grains of dust will be found precipitated under these openings. The finer parts settle more slowly in the open chamber. The more there are of these partitions the more complete will be the precipitation of dust; but at the same time the labor of the mill, in throwing the air forward, will be increased.

At the extremity of the dry chamber is an opening, twelve by eighteen inches, *or more*—never less than that—into a wooden pipe of equal dimensions, which brings back the entire body of air, and conducts it, with a small residuum of dust, into the box of the auxiliary fan, which we will call the second fan or counter-blower.

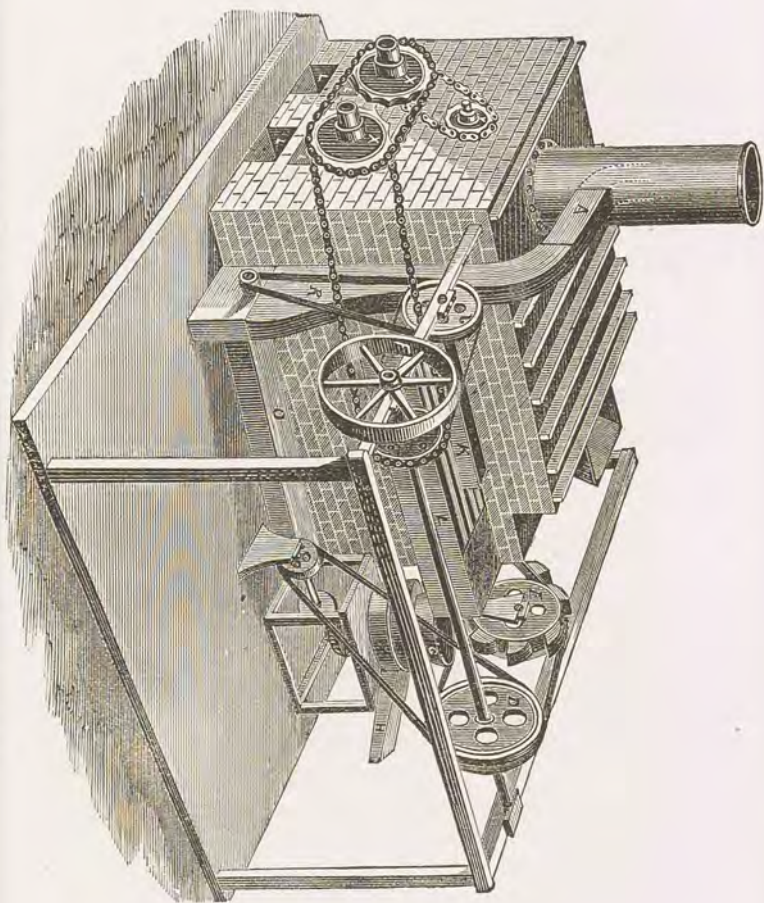
Another form of chamber, the same in principle with the one used for dry grinding, we think superior to all others. It consists of a series of large hoppers, furnished with an apparatus for drawing off the dust while the pulverizer is in action. This improvement is represented by Fig. 58. Three or more hoppers may be used, or one very large one, with partitions. These should be strongly framed and suspended from timber-work by iron rods. We believe this form to be the best for ores, more especially because it obviates the necessity of stopping mills to clear out the hoppers.

CCC, represent auxiliary hoppers, to be filled and emptied during the action of the mill; *PP*, rings for raising partition, *a*, to convert both half-hoppers into one; bin *B* is made in two apartments, but raising gate *a* by rod *c* connects the two, making but one; slides *s* are for letting the dust out of the bins; bin *B* has two slides, one for each apartment.

Figs. 60, 61, and 62 illustrate Messrs. Crosby & Thompson's gold-mining process. This process, intended for the reduction of such ores as those of Colorado, in which iron pyrites and other sulphurets exist in large quantities, employs two distinct sets of apparatus—one for roasting the ores, previously pulverized and treated with



a strong solution of common salt, and the other for amalgamation. The first consists essentially of a furnace, con





taining three revolving cylinders, the upper one of which is used as a drying cylinder, *J*, Fig. 60, from which it passes by a forked conductor to the roasting cylinders, *R*, Fig. 60, which are driven by the pulleys *X*. Through the centers of these pass large pipes, *P*, Fig. 60, open at both ends and perforated with small holes, through which an abundant supply of air reaches the ore. From these cylinders the solid substances are discharged through a trap at *a*, Fig. 60, while the gases pass into the gas-chamber, *o*, Fig. 60, which is connected with a condenser, consisting of a series of cooling-tubes and a spray-chamber, in which the particles of ore and gold which have been mechanically transported by the draft are detained and a portion of the gases condensed. The draft is obtained by means of a fan, situated at *R*, in Fig. 61, and the residual gases pass into the chimney at *A*, Fig. 61. The position of the condenser and the tank on the perforated top of the spray-chamber is shown at *L* and *K* in Fig. 61. The solid materials are brought by an elevator, *E*, Fig. 61, to the wooden grinders, *c*, by which the lumps formed in roasting, which would interfere with the amalgamation, are reduced to powder and discharged through the spout *H*, Fig. 61.

The amalgamating apparatus consists essentially of several series of amalgamated copper plates, over which the pulverized ore in suspension in water is carried, and in the lower portion of the apparatus it is rubbed by amalgamated copper plates under the surface of quick-silver, and under the pressure of a head of seven or eight feet of water. The ore, largely diluted with water, passes through the upper perforated plate, *D*, and falls in a shower upon the inclined amalgamated copper plates, *E*, after which it traverses another perforated plate and series of amalgamated plates. The whole of this upper portion of the apparatus is kept in continual vibration by means of the cam *Z*, Fig. 62. The ends of the copper plates are a little turned up, as seen in Fig. 62, which aids in retaining the coarse particles of gold, and experience has proved that about one third of the gold contained in the ore, or nearly as much as is on the average

obtained by ordinary amalgamation, collects in this part of the machine. From the chamber, *B*, the ore passes through *G* to the under surface of a slotted plate, *II*,

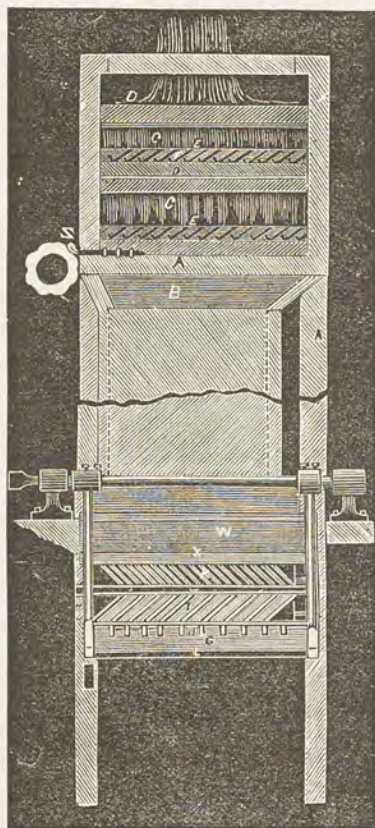


Fig. 62.

through which it passes to the under surface of the amalgamated copper plates, *I*, which are inclined at a high angle, and of which there are three for each slot, thence

through the perforated plate, *J*, to the second series of amalgamated plates, *K*, which are more numerous than those at *I*. The space from *L* to *X* is filled with quicksilver, and the slotted plate *H* and the perforated plate *J* are kept in a state of constant vibration by means of the rods, etc., *M N*, Fig. 62, which are connected with the moving power. The ore in passing through this lower part of the apparatus is so thoroughly and forcibly rubbed between two surfaces of quicksilver, which from the inclination of the plates and their repetition are made very large, and any tendency to cake together is counteracted so completely by its compelled passage through the vibrating slotted and perforated plates, that it is scarcely possible for any considerable amount of gold to escape amalgamation. The inventors state that they can obtain by this machinery ninety per cent of the gold shown by a good wet assay. After escaping from the apparatus at the level, *W*, up to which it remains full of water, the exhausted material, in order to avoid any possible loss, is passed through additional perforated plates and over amalgamated copper plates (as shown in the lower part of Fig. 62) as many times as may be convenient or desirable.

The chemical reaction involved in the roasting arrangements are not new, but the apparatus seems calculated to do its work with great perfection; while the arrangements for amalgamation seem to secure more perfect contact of every particle of the ore with the quicksilver than any of those hitherto employed.

We here introduce the description of the furnace employed by Messrs. Whelpley & Storer for the desulphurization of gold ores and the separation of gold from the quartz. Their description of the state in which gold exists in its ores, and of the principles on which its extraction should be conducted, are of so much general interest, that we quote them almost entire.

"The particles of gold in a quartzose gangue or matrix are often extremely small, so as to float and be carried away by water, especially if buoyed up by the adhesion of a small particle of quartz.

"This fineness is so excessive sometimes as to give what is called a color to the quartz; the separate particles of the metal being invisible under a microscope of ordinary powers.

"It is impossible, by any mechanical means, to pulverize quartz so finely as to uncover all these minute particles. They are protected by an envelope of quartz from the action of mercury.

"The loss by this means sometimes exceeds fifty per cent of all the gold in the ore.

"To effect a complete separation of the metal from its gangue, it is necessary, at first, to pulverize by the best mechanical appliances; and, secondly, to plunge these minute particles, after first bringing them to a red heat, into a water-bath.

"By contact with the water, they are exploded into still minuter fragments. The metal having a different expansion from that of quartz, is released from its adhesion to the latter, even to the minutest conceivable form.

"But, in the course of this process of heating and quenching in the presence of atmospheric air and moisture, a complete separation of sulphur, arsenic, and other volatilizable substances, supposed to prevent the action of the mercury upon the gold, is effected.

"We consider this latter operation, however, much less important than the first. As the gold is probably not in chemical combination with the sulphur or arsenic, the incrustation of these latter in the form of sulphites and other combinations will be effectually removed by the process of heating and quenching.

"We have, therefore, constructed our furnace with a view more especially to the heating and quenching process, and have made every part of it subservient to this result.

"We pulverize the ores as finely as possible by mechanical means, bring them to a *white* heat, and plunge them instantly into water.

"The product of this operation is a plasma or mud of quartz, so fine as to be nearly impalpable, and to be nearly indistinguishable into particles by the microscope.

"In this manner the particles of gold lie by themselves, without adhesion to the gangue.

"If the quartz contains scale gold, the foliaceous particles are rolled up into pellets by the double effect of rapid trituration in the mill, and subsequent dropping through the furnace-fire.

"It is, consequently, not necessary to pass the entire mass of plasma or ore over the surface of mercury—a slow and costly operation; but, by the simple washing of water, almost the whole of the gangue may be removed.

"This is not the case with scale gold imperfectly separated by stamps; being in the condition of thin laminae, it floats away and is lost.

"The furnace is so constructed that none of the ore-dust can adhere and collect in the downward flue, nor escape through the smoke-stack.

"One furnace will desulphurize from *one* to *four* tons of ore an hour; the amount depending upon the quantity of sulphur and other volatilizable substances to be removed."

Figs. 63, 64, and 65 represent the series of crushing and grinding machines invented by Mr. P. G. Gardiner.

No. 63, crushing machine, for wet grinding, is an oscillating kettle carrying a ball of about four thousand pounds weight, the movement being such as to reduce any kind of quartz or metallic ore into an impalpable powder, at about a rate of one ton per hour, with a power not exceeding five-horse. This machine has a steady oscillating movement, giving to the ball (which is entirely free) a compound rotary movement, continually changing its position. The *entire surface* of the ball is thus brought in contact with the surface to be ground, thereby accomplishing a greater amount of perfect grinding with less power than any machine ever before constructed. It is fed at the top—of sizes usually fed to stamps—and is discharged through a cone in the center of the machine, passing out underneath to any desired point.

No. 64, mulling machine, is for dry or for wet grind-

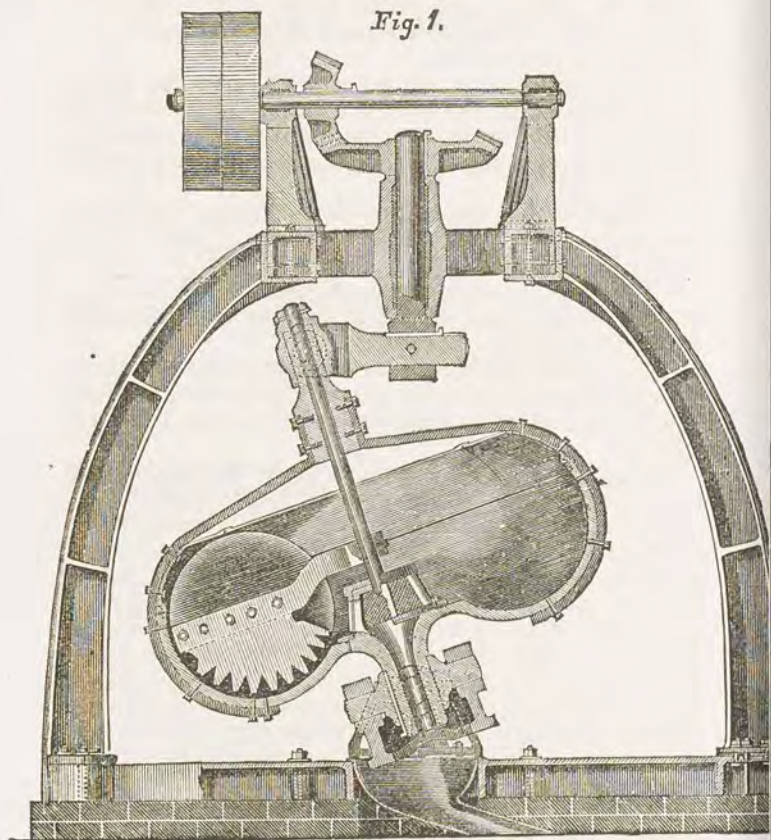
Fig. 1.

Fig. 2.

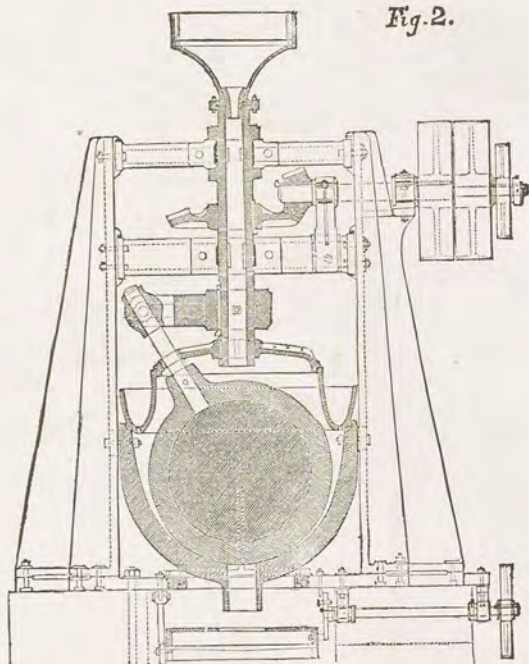


Fig. 64.

Fig. 3

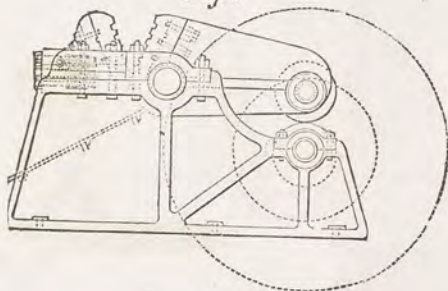
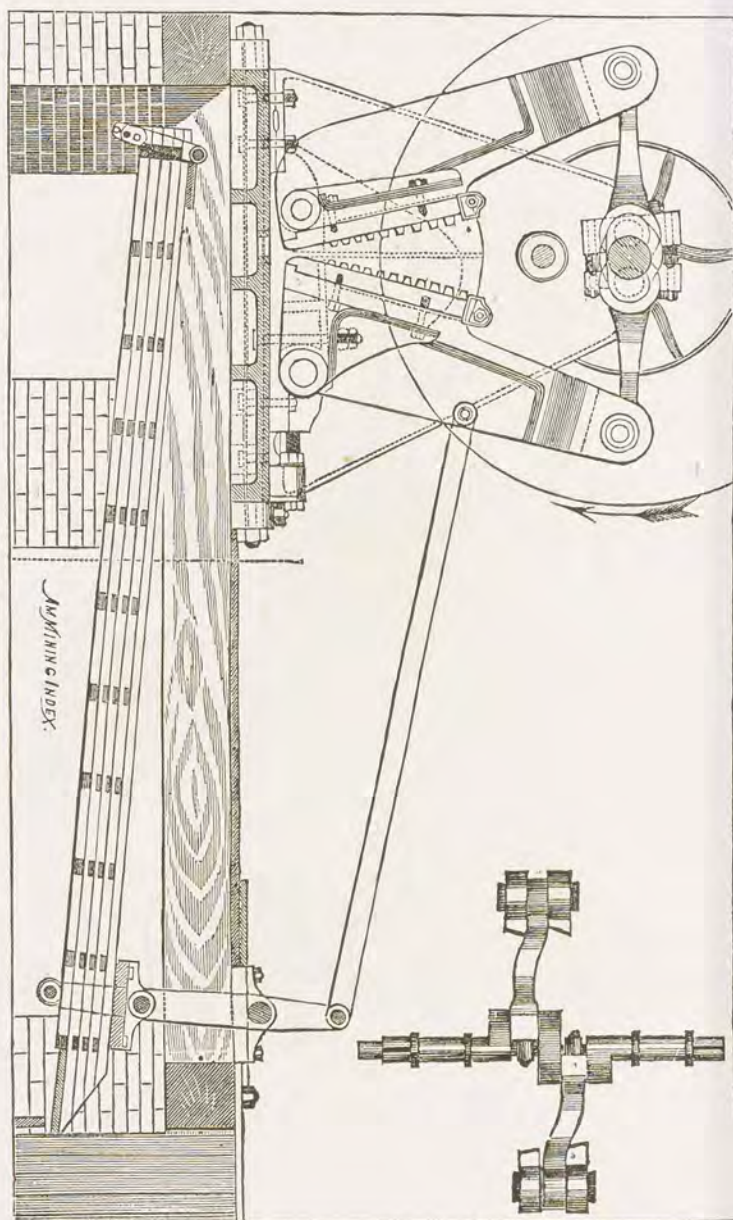


Fig. 65.



ing. Will reduce to an *impalpable powder* about one ton of ore per hour with about eight-horse power. Its construction is simple and its operation very effective. It is composed of a pot or mortar having a close-fitting revolving cover, to prevent the escape of dust, with a ball of about six thousand pounds weight, nearly fitting its inside surface, which ball has a shaft connecting with a crank, by which it is rapidly revolved, giving not only the motion of the pestle and mortar, but also a revolving and an oscillating movement besides, all of which serve to complete the perfect grinding and the discharge of the ground material through the centre or bottom of the kettle.

No. 65, cracking machine, receives the ore in large lumps, reducing them to the size of peanuts and downward to the finest powder, about one third of which will pass through a seventy sieve which is attached to the machine, the balance being ready for either crushing machine No. 63 or 64. With three-horse power, this machine will crack and pulverize about one ton per hour; but an increased power and velocity will increase the ratio correspondingly. This machine is constructed with an adjustable spring-head, to *prevent breaking* if pieces of iron should get into the jaws by accident or otherwise. It also has a *raking forward and downward* movement, which makes it so much superior in its action to any other machine designed to secure the same result, now in use.

Fig. 66 represents Mr. Gardiner's "Thunderbolt Crusher." Engineers and mill men will readily understand how it operates by examining the illustration, as all the parts are drawn to a scale. The jaw-plates have facings cast of white iron, chilled and hardened, of which many may be furnished. These facings are cast with a graduating series of teeth or short projections, the longer of which are above, until this series reaches the lower end of said plates, when these terminate in the smooth surface, where the *attrition* is produced. The crusher can conveniently receive boulders of fifty pounds or

more, and the effect produced by their rapid disappearance is astonishing.

The crushed ore passes into an aperture under the plates, where a long chamber incloses the vibrating-screens, of which there are four; the upper screen is only for conveying the larger grains, by means of elevators not herein shown, back to the plates; the middle screen sieves the ore to a sufficient fineness for roasting or calcination; the third and fourth, or lower screens, give the impalpable powder.

The entire weight of the crusher does not exceed six

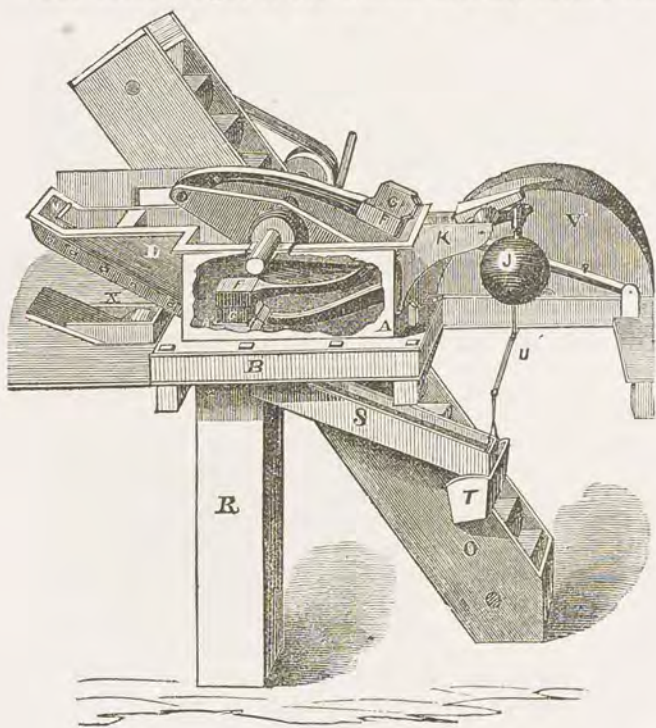


Fig. 67.

tons, and it is capable of crushing forty-eight tons of ore to an impalpable powder.

The principle that appears most conspicuous and novel is, that the two face-plates, as seen in the diagram, describe different circles, for the purpose of producing the motion for attrition, yet the eccentric acts uniformly upon both plates. This has been the great problem to be attained, to reduce the ore by attrition or rubbing to impalpable fineness, especially where the ores contain sulphur and other base metals.

Fig. 67 represents the hammer quartz-mill of Messrs. Rix & Logan, of San Francisco. The hammers *F G* are made to revolve by means of the shaft *C*, and strike upon the die, *H*, upon which the quartz is deposited anew, at every blow, by the plunger, *M*, running up and down the feed-spout, *L*. From the die the hammer is drawn backward, and with it the partially crushed quartz, the hammer gliding along the spring-bar, and the quartz following through an opening upon the sieve, *S*, through which the dust passes, while the coarser particles are carried by the spout, *T*, into the elevator, *O*, and then returned to the feed-spout to be re-pounded.

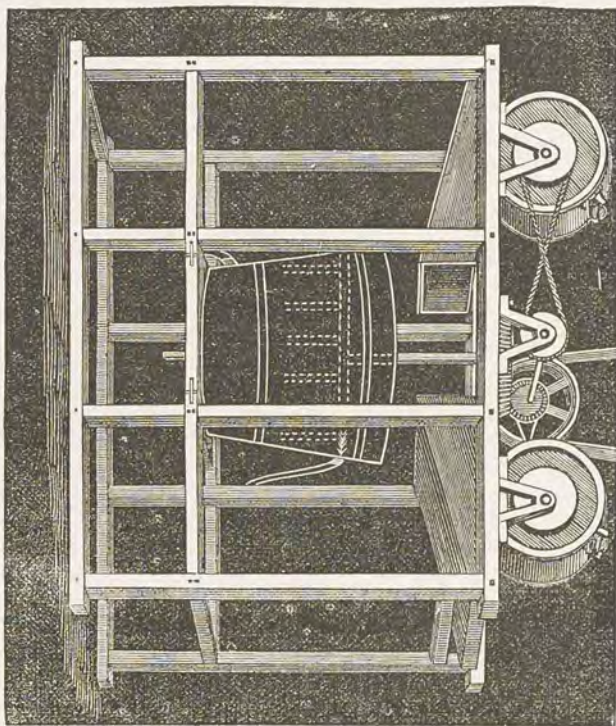
Fig 68 shows Mr. Ed. N. Kent's arrangement of barrels for amalgamating. The ore and amalgam, after the barrels have been made to revolve for a sufficient length of time, are discharged, by means of the large spouts shown, into the agitator below, at the bottom of which the amalgam accumulates. In connection with this figure some extracts may be given from Mr. Kent's account of his improved mode of reducing ores of gold and silver :

"By this 'improved mode of preparing ores,' the ore is not only desulphurized in the best and cheapest manner, but the base metals are converted into soluble *chlorides*, which are *not* readily decomposed by heat, and may be subsequently removed by washing the prepared ore, or by the water used in the process of amalgamation, and the gold is thus left free and bright, and in the best possible condition for combining with the mercury used in that process.

"To effect this object, the crushed ores or tailings are

simply mixed with a solution of common salt, and made into cakes, lumps, or bricks, which are then calcined in a common kiln, such as is used for burning lime or bricks. In this process, the sulphur in the ore is oxydized by the oxygen of the atmosphere, and the sulphuric acid thus produced immediately combines with the soda in the

FIG. 63.



salt, forming sulphate of soda, and liberating the muriatic acid, which in its turn attacks the base metals, forming chlorides of copper, zinc, antimony, etc., together with chloride of silver, and leaving metallic gold. All the acid used in the process is prepared in the process itself, and the chemical changes are produced in the nas-

cent state, which is the most favorable condition for effecting them, and the sulphur being thus combined with the soda, a smaller proportion escapes into the atmosphere than when ores are simply roasted alone.

"By the application of the salt in solution, one bushel will make sufficient for a ton of ore; and by making the ore into bricks, which may be done with one machine, at the rate of twenty-five tons per day, the use of expensive reverberatory furnaces, as used at Freiburg, is avoided, and twenty-five tons of gold or silver ore, in a common lime-kiln, or twelve hundred tons in a brick-kiln composed of the caked ore in the form of bricks, may be calcined at one operation, in the cheapest and best manner, without *any* furnace at all, by the passage of a current of hot air through the interstices of the brick so formed.

"After the chemical decomposition of the ore is thus effected, it becomes so soft that it may be ground with common burr-mills, at the rate of forty bushels per hour, for amalgamation in barrels, or it may be ground and amalgamated at the same time, by the use of the Washoe pans. When two different kinds of ore are mixed together, in suitable proportions, before caking, which is sometimes of very great advantage, and the calcination and amalgamation are done in the best manner, about five times as much gold or silver as from crude ore, or from seventy-five per cent to the full assay value, may be obtained."

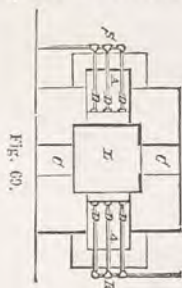
Figs. 69, 70, and 71 represent the furnaces employed by the "Colorado Gold and Silver Separating Company"

in working the patent of Dr. William E. Hagan. The references to the letters sufficiently explain the structure of the furnaces. The following extracts from the Company's report will show the nature of the process, to which are added some practical directions for putting it in practice.

A—Furnaces.

B—Blast-holes.

C—Delivery-openings.



D—Perforated steam-pipes.
E—Superheated chamber.
G—Flue, 8x8.
I—Dampers.
L—Bridge-wall of furnaces.
M—Flue, 18x18.
N—Opening, 24x24.

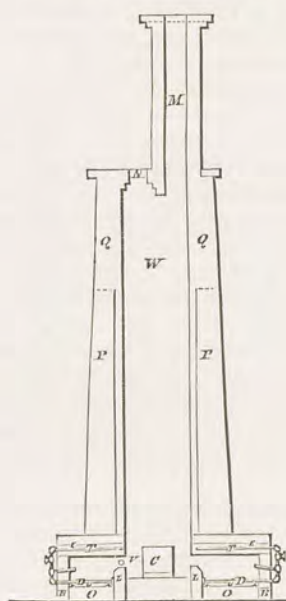


Fig. 70.

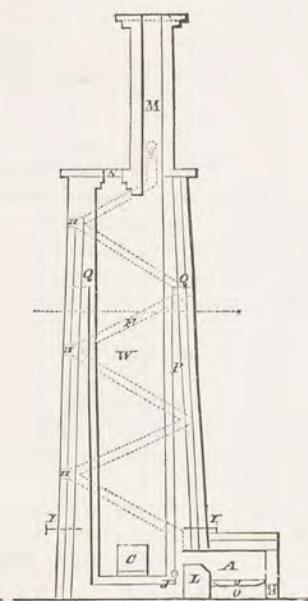


Fig. 71.

O—Ash-pits.
P—Stone walls to save brick.
Q—Brick walls.
R—Wood furnaces.
S—Coal furnaces.
T—Pipes for superheated steam over furnaces.
U—Grate-bars.

V—Steam pipes for controlling the action in the reducing-chamber.

W—Reducing-chamber.

"The following is an explanation of the *rationale* of the Hagan process for disintegrating and desulphurizing gold and silver ores. Superheated steam is introduced into the fire in such a manner that, in a gaseous form, the steam impinges upon the ignited coals or wood, without admixture of atmospheric air, and thus effects the decomposition of water into oxygen and hydrogen gases. The oxygen unites immediately with the carbon of the burning coals or wood, while the liberated hydrogen passes from the fire and burns in the presence of the oxygen of the air. The hydrogen flame and the resulting gases being brought into contact with the heated gold and silver ores, the sulphur, arsenic, antimony, etc., are dissolved, and are carried off with the products of combustion. The powerful effect of the flame of hydrogen, in dissolving pyritous sulphur, arsenic, antimony, etc., and in attacking oxygen, is well known, but the expense of producing it has hitherto prevented its application to the disintegration and desulphurization of gold and silver ores. Not until the invention of Dr. Hagan's cheap and simple method of decomposing water and thus furnishing hydrogen gas and flame abundantly, has it been at all possible to apply it to this purpose; but now so economically can this powerful agent be produced that the cost of treating ores by it is only one dollar per ton.

"The treatment of gold and silver ores by the Hagan process requires a furnace of very simple and inexpensive construction, which may be built of materials at hand in every miner's locality, costing not over two thousand dollars, for working fifty tons per day. The ores are fed in at the top of the furnace as they come from the mine, and are drawn out at the bottom as soon as they become disintegrated and desulphurized, and thus the operation is kept up, day and night, uninterruptedly, the ores requiring forty-eight hours to pass through.

"The ores thus treated become soft and friable, and

their character will be destroyed, so that they will crumble into powder under slight pressure. The sulphurets of iron, copper, and other base mineral compounds, will be converted into oxyds. The finest particles of metallic gold will be liberated from their inclosing matrix, and the silver ore will be put in a chemical condition suitable for perfect amalgamation, so that both the silver and gold may be easily separated, without the great waste and losses attending the old methods of working the ores.

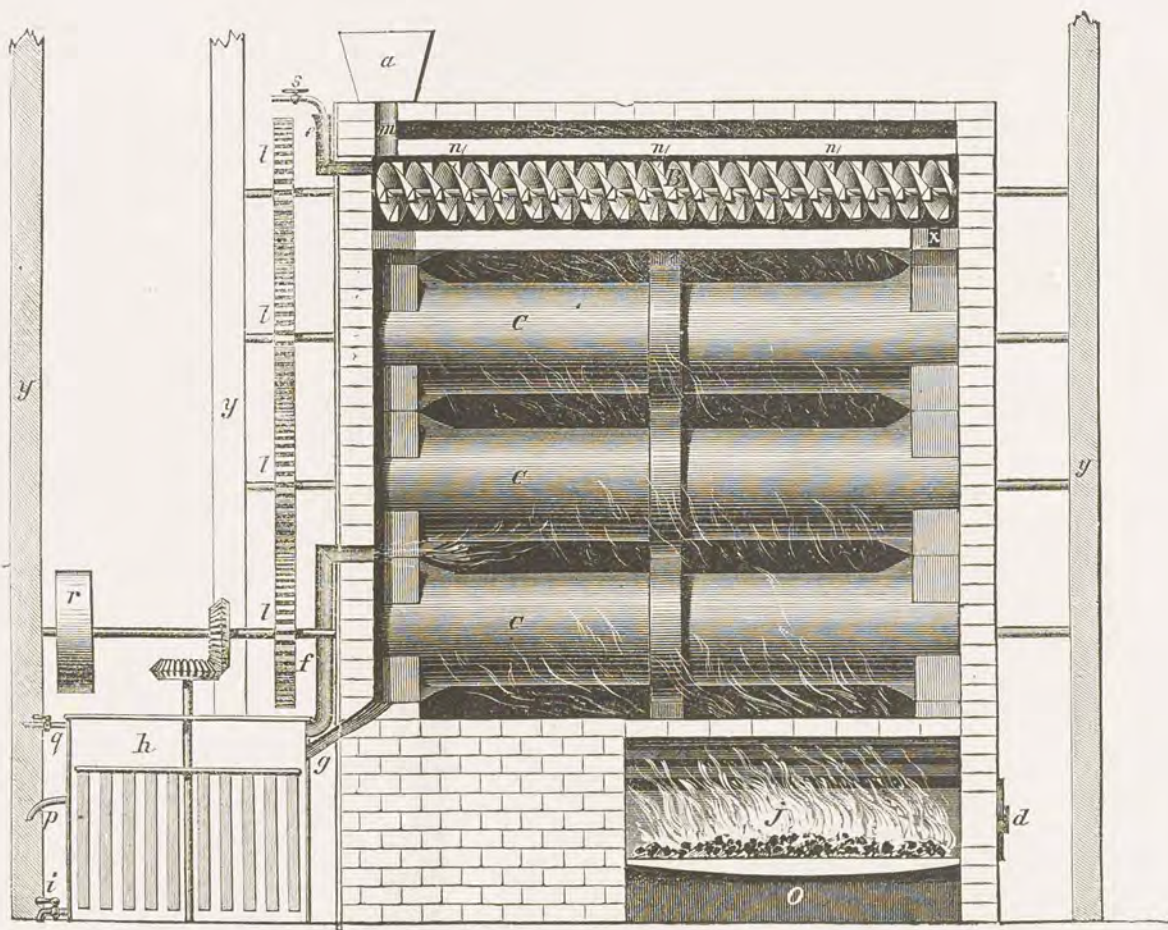
“When properly manipulated, the ores can be made to render all the precious metals they contain, or, say, within five per cent of the assay—whereas, by the ordinary method, the miners of Colorado have only obtained twenty-five dollars per ton from ores actually containing from one hundred dollars to five hundred dollars or more per ton.”

WORKING DIRECTIONS.

Fill the furnace with ore broken six to eight inches square, put fire under, and work very moderately for twenty-four hours; then make the fire strong, and let the ore remain in forty-eight hours longer. At the expiration of that time, commence to draw out, taking out two tons per hour, at the same time putting in a like quantity; thus keeping the furnace always full, and bringing the ore gradually from a temperature of about three hundred degrees at the top to a temperature of about nine hundred degrees as it falls to the bottom of the furnace.

Let in steam at the bottom of the furnace, for ten minutes, each time before taking out ore, which cools it. After taking the ore out of the furnace, it should be run through some grinding process to bring it down to fine sand. It should then be run through the second process, which should have a strong wood fire and good supply of hydrogen gas, as the time running through would be very short; after which it should be put in some amalgamating process, such as Beeth's, which grinds to fine powder as it amalgamates, and clears off the oxyds at the same time.





DR. RILEY P. WILSON'S DESULPHURIZER.

WILSON'S DESULPHURIZER.

DR. RILEY P. WILSON, the patentee of this Desulphurizer claims for it the following virtues:

FIRST. The pulverized ore is forced over the *inner* surface of *fire-clay* retorts, maintained at a *cherry-red* heat.

SECOND. The ore while passing through the retorts is continually stirred, thereby exposing all parts of the ore repeatedly to the heated surface.

THIRD. While the ore is being conducted through the series of retorts, a current of air and steam *combined* intermingles with it, causing the ores to be rapidly oxidized.

FOURTH. The chemical changes that occur in the above process are those demanded by the true conditions of desulphurization.

FIFTH. The sulphates—formed by the action of sulphuric acid upon the ores during the process of roasting—are injurious to the process of amalgamation. To overcome this condition, the desulphurized ores are discharged into a receiving vessel, partly filled with hot water. The sulphates being soluble in hot water, the ore is thereby left in the best possible condition for amalgamation.

SIXTH. During the process of removing the sulphurets as the ore passes from one retort to the other, sulphur is rapidly separated from the ore, and is subsequently conveyed into the furnace, thereby furnishing a large amount of the fuel, to “consume itself.”

SEVENTH. A large portion of the precious metals is thrown out by the draft of ordinary furnaces. By the new process all the mineral is saved by conveying the ore *inside* the retorts during the process of desulphurization. It is also possible to apply too much heat in roasting ores; a cherry-red heat is by far the best; a condition it can always fulfill. The heat by this process is also applied in such manner as to gradually increase to the discharging receiver.

EIGHTH. The materials of the furnace are constructed

of ingredients that will resist the action of the gases of sulphur, as well as the acids and other destructive agents found in most ores, for years. A very small quantity of fuel will produce the requisite amount of heat, as the gases of sulphur are consumed in the furnace.

NINTH. It is compact, and requires but a small amount of power to run it.

A Desulphurizer comprising all these advantages must be a valuable invention, because without desulphurizing sulphureted rock, a vast amount—in gold, about four-fifths—of metal is lost. Its mode of work is certainly very neat and simple, while its form is compact. It is a great *desideratum* to disintegrate and desulphurize, without handling, the pulverized ores in the furnace. By this method, the raw ores are put in at the top, are roasted in the furnace, and enter the amalgamator and become amalgamated, all without handling.

LYON'S SMELTING PROCESS.

To work ores by this process, the ore must first be crushed by stamps or some similar process; it then passes to the buddle. This machine consists of a large circular vat, about two feet deep and twenty feet in diameter.

The bottom is smooth, and is elevated in the centre a few inches higher than at the outer edge. Over this bottom or floor four arms revolving about the axis in the centre of the vat, to which tufts of long hair are attached at intervals of about two inches, are made to sweep. These preserve a smooth surface, and by carefully stirring the ores, cause the lighter portions to wash away to the outside. The pulverized ores are fed into a hopper at the centre, and with them a current of water is admitted. The water washes the pulverized ores down from the centre toward the outside or circumference. The galena, if any is contained in the ores, is left around the centre or axis. The sulphides of copper and iron come next, and the white quartz and sandy portions are carried to the outside. The galena contains most of the silver and some gold, while the copper and iron sulphides contain some silver and nearly all the gold, and the silicious or sandy portion outside contains so little of either, that it is cast aside as worthless. In this way one half the bulk of the crushed ore is removed, and at the same time at least ninety-five per cent of the gold and silver retained. Between the pure sulphides and pure sand is a portion containing both, which is thrown aside to be run through again. By this means the ores are very perfectly separated.

That portion composed of galena, if any such there may be, may then be smelted in Scotch hearths. These consist of a cast-iron vessel, similar to a caldron-kettle, with an aperture for discharging the metal. Over this a cupola is erected.

The method of using a Scotch hearth is this: If the ores are a native galena, they are first broken to the size of a walnut, or in case of mixed ores, they are taken from the buddle, and laid in the hearth with alternate

layers of finely split wood from a foot to eighteen inches long.

The wood is then ignited, and a blast of air amounting to about two pounds to the square inch is applied. The lead is readily smelted out, and carries with it the gold and silver contained in the ore. The whole is drawn off in pigs or ingots at the bottom, and is ready for cupellation.

The sulphides of iron and copper, after separation by the buddle, are placed in a reverberatory furnace, so constructed as to roast and not smelt the ores. In general the reverberatory furnace is quite similar to a baker's oven, except that it is so constructed that the fire is constantly kept up. For roasting, the roof of the furnace is so shaped that the flame of the fire will pass along over the ores without impinging or striking them; for smelting, on the other hand, the flame is thrown down upon the ores. After roasting, the ores are placed in a smelting reverberatory furnace, mixed with a quantity of protoxide of lead or litharge, varying in amount from one fourth the amount of the ore to very much larger proportions, sometimes many times the weight of the ore.

Other chemicals are used as fluxes as the occasion may require, and should sulphur still remain at the smelting, a quantity of old iron is thrown in to absorb it. The gold and silver contained in the bars of lead is then separated by cupellation.

The furnace for this consists of a concave iron hearth, lined to the depth of several inches with bone ashes wet up with water. These bone ashes are prepared by burning bones until they become perfectly white, and then grinding them to flour. Upon this hearth the lead is placed, and a fire is lit in the furnace below and around the hearth, and a blast is applied. A portion of the lead is converted into litharge on the surface of the melted metal, and is blown off into a chamber prepared to receive it. Another portion is absorbed by the bone-ashes, and carries with it any copper or other base metal which may remain. When all the lead is driven off in this

way, the remaining metal suddenly brightens, and the work is done. What remains is gold and silver.

The bone-ash is afterward smelted for the lead it contains, and is ready for use again. The loss of lead is about five per cent each time it is used, and will not be greater, provided the furnace is properly arranged.

BEHR AND KEITH'S PROCESS.

This process is now, and has been for some time, in practical, profitable every-day operation; and it may be safely said of this process, imperfect as it now is, that, if no better one is ever discovered, Colorado ores which will not pay to run in a stamp and pan-mill, can be worked steadily and profitably, even at the present high rate of labor and materials, by this process. The principle seems to be similar to that of Messrs. Crosby & Thompson's Desulphurizer—that of operating upon powdered ore by the action of heat and oxygen, the method of application, however, being different. By this process no cylinders are used, the ore being forced by a strong draft through a brick furnace and long flue, by which the ore is roasted and smelted in the air. It is claimed by this process, as well as by that of Messrs. Crosby & Thompson, that the infinitesimally fine particles of gold are aggregated in small round pellets or globules. This would seem to be conclusive upon an examination of the gold with a strong glass. Many of these small globules appear to have a small concave indentation upon the surface, while others appear to have burst open from the natural shrinkage of the ore from a molten state.

The expense of this process would seem greater than that of Messrs. Crosby & Thompson, while the result can not be more satisfactory, and it certainly has not the merit of equal simplicity; but, from the fact that this process has been and is now successfully at work, it would at the present moment seem to stand ahead of any other.

The present winter, however, will probably decide the question of merit between the different processes.

MASON'S PROCESS.

Mason's process for disintegrating and desulphurizing ores consists in introducing super-heated steam into a fire in such a manner, that in a gaseous form the steam strikes upon the ignited coals or wood, without admixture of atmospheric air, and thus effects the decomposition of water into oxygen and hydrogen gases.

The oxygen unites immediately with the carbon of the burning coals or wood, while the liberated hydrogen passes from the fire and burns in the presence of the oxygen of the air.

The hydrogen flame and the resulting gases being brought into contact with the heated gold and silver ores, the sulphur, arsenic, etc., are dissolved, and are carried off with the products of combustion. The powerful effect of the flame of hydrogen, in dissolving pyritous sulphur, arsenic, antimony, etc., and in attacking oxygen, is well known; but the expense of producing it has hitherto prevented its application to the disintegrating and desulphurization of gold and silver.

Not until this cheap invention and simple method of decomposing water, and thus furnishing hydrogen gas and flame abundantly, has it been at all possible to apply it to this purpose. Furnaces are now operating by this process in California, which receive charges of sixty tons, and are eminently successful. It is claimed that by this process in Colorado \$100 per ton have been obtained, and from ore which yielded but \$4 per ton in a stamp and pan-mill. Extensive works are being built to demonstrate this process, under the direction of Mr. Kenyon, who claims that he will save 95 per cent of the gold and silver contained in the ores, as proven by assay, and that he will sell the process subject to such guarantee.

ALFRED MONNIER'S PROCESS

For the Metallurgical Treatment of Sulphuretted Ores.

The following is a *resumé* of Mr. Alfred Monnier's Desulphurizing Process: The process with which we have to deal in this article has been applied heretofore mainly to cupriferous or nickeliferous ores, but is equally susceptible of employment in those cases where gold and silver occur with the sulphides of iron and copper, as will be seen from the description and details below given. The Carrol Mining and Manufacturing Company erected works at Cranberry Plains, Va., as early as 1861, and employed Monnier's method from the brief period elapsing from the inception of their enterprise until the commencement of the rebellion, producing and sending to market in that time upwards of 80,000 pounds of copper. But one of the most prominent and valuable features of the "process" was not employed at these works, viz: the utilization of the eliminated sulphur for the manufacture of oil of vitriol. During the past year Mr. Klett, of the firm of Potts & Klett, of Camden, N. J., has erected and put in most successful operation large furnaces [as in Fig. 1, and of which Fig. 2 is a sectional drawing,] for the treatment of such ores, utilizing the gas produced, by converting it into sulphuric acid, thereby not only completely revolutionizing the old process, in which Sicilian sulphur is employed, but rendering practicable the treatment of exceedingly poor cupriferous ores. So thoroughly is the desulphurization effected at these works that the amount of acid theoretically called for from an analysis of the ore is practically produced. The method is based upon the extraction of the copper (or silver, nickel and cobalt, according to the nature of the ore treated,) in the form of sulphate, by the employment of sulphate of soda, the gold remaining in the residual and desulphurized oxide of iron in a condition to be readily amalgamated. The sulphur evolved in the form of sulphurous acid is easily converted into sulphuric acid. The ore proposed to be treated is crushed with the sulphate of soda by means of Blake's Rock Breaker and the Cornish Rollers, to a degree of fineness sufficient to permit it to pass a sieve with twenty holes to the inch, and then calcined in a muffle-furnace eighty feet in length by six feet in width. The sole of the muffle upon which the ore is placed is built of tile, four and a half inch thickness, under which travel the heated gases from the fire-place at the end of the furnace; no communication existing between the fire chamber and the muffle, the ore being reached and manipulated

through a series of doors placed along one side of the furnace. Through these doors the ore is stirred and turned over once an hour, being gradually worked down from the rear end of furnace, where it is recharged through a hopper into the muffle, towards the front, where it is discharged. The ore is thus gradually heated and by the presence of the sulphate of soda, most of the sulphur is eliminated and a large amount of sulphates of the oxides of iron and copper (silver, nickel and cobalt,) produced. When the charge reaches the front of the muffle, in the immediate vicinity of the fire box, and where the temperature is most elevated, the sulphate of the oxide of iron is decomposed, producing oxide of iron, some *bi* sulphate of soda, and *completely* converting the copper (silver, nickel and cobalt) into soluble sulphates. This stage of the operation requires care in the management of the temperature, since, by too low a degree of heat the iron may not all be converted into insoluble oxide, or, by too great an elevation of temperature, some of the other metals may be rendered insoluble by a deprivation of their sulphuric acid. If it be the object of the operation to manufacture oil of vitriol as well as to extract the metals, the register, placed at the end and above the fire-box, must be regulated so as to admit the quantity of atmospheric air requisite to the oxidation of the sulphur in its passage through the length of the muffle—the exit pipe for the sulphurous acid gas leading from the rear end of the muffle, close to the charging funnel, into the oil of vitriol chamber. The ore thus calcined is lixiviated with water to extract the sulphates of copper, silver and soda (cobalt and nickel), and the insoluble residue consists of oxide of iron and earthy matters, and contains, if the ore treated has been auriferous, all the gold. The method of lixiviation [see Fig. 3.] is the same as that practiced in soda works for what is called “black ball;” that is to say, the calcined ore is placed in a series of tanks [A. A.] having false bottoms, serving as filters. The warm water, introduced at the top, percolates through the mass, dissolving the sulphates, and, passing through the filter, is raised through a leaden pipe (placed vertically through the ore and communicating with the space under the false bottom or filter) into another similar tank charged with the calcined ore, and thus through the series, becoming more and more saturated with the soluble salts. If the residue [collected in agitator c.] after lixiviation contains only oxide of iron and gangue, it is thrown away; but should the ore treated have been auriferous, the insoluble residues contain the whole of the gold, *perfectly free from sulphur*, which may easily be ex-

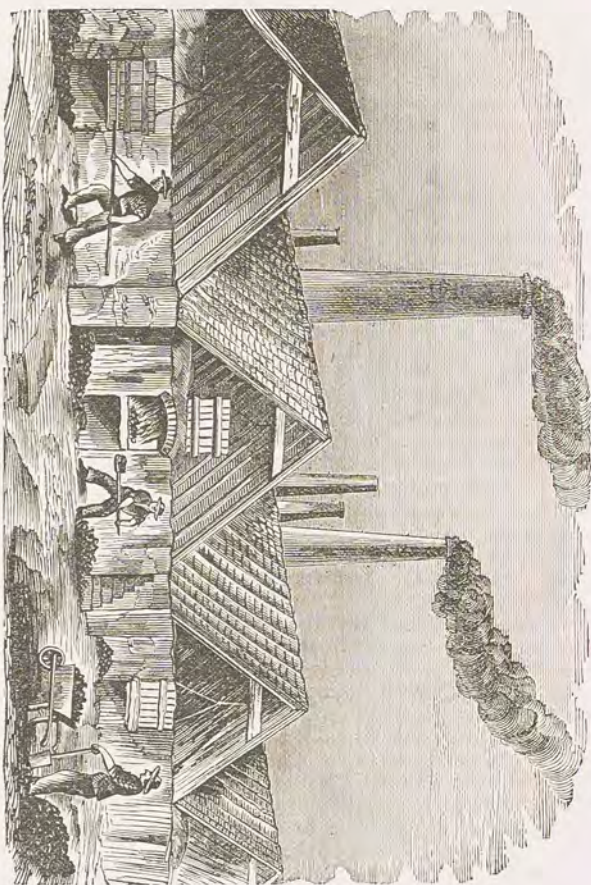


Fig. 1.—FURNACE.

tracted by first re-grinding the mass in a Behr mill, and then passing it through a series of three Tyrolean amalgamators. The preliminary grinding requires but small power as the calcined ore is very friable. With three amalgamators the operation is perfect, as has been demonstrated on a large scale in North Carolina. The solution containing the sulphates is treated according to the metals present. If cobalt and nickel are present in sufficient quantities, the operation becomes exceedingly complicated. The liquor containing the sulphates of soda, copper and silver is treated as follows: the silver is first precipitated by means of plates of copper, and subsequently this added copper, as well as that existing in the ore, is removed from the solution by cast iron, after which it is evaporated to dryness to recover the sulphates of soda, which may thus be repeatedly used for the calcination of fresh ore. The metallic copper and silver so obtained are separately worked in the usual way. The copper is so pure that it requires only a single fusion to produce ingots of the first quality. The precipitation is made in a reverberatory furnace of peculiar construction. In a wooden trough (54 feet long, 10 feet wide and 2 1-2 feet deep) is a leaden pan (of 10 pounds to the square foot) of the same dimensions, the bottom of which is covered by a two-inch floor of wood, and the sides of which are protected by a nine-inch brick wall, extending one foot above the sides of the leaden pan, and the whole covered with a low arch and well braced. Along one side and above the leaden pan is placed a number of working doors, through which the copper is removed after precipitation. The plates of cast iron (2 feet long, 1 1-2 feet wide and one inch thick) are placed across the furnace at intervals of one foot, so as to form partitions. At a distance of two feet from the end of the furnace is constructed the fire-box, which connects by an arch with the arch of the precipitating furnace, and the gases from which are discharged from a stack in the latter arch. The liquid to be precipitated is then introduced into the furnace to the height of the leaden pan, and removed after the precipitation of the copper by means of a large plug at the bottom of the furnace. The fire is very moderate, the object being to create a reducing atmosphere, to prevent the oxidation of the protoxide of iron, the presence of which would cause a loss of cast iron. The evaporator is of similar construction, except that the arch is close to the upper edge of the leaden pan, so as to compel the heat to travel as close as possible to the surface of the liquid to be evaporated, but at a distance of ten feet from the fire-box

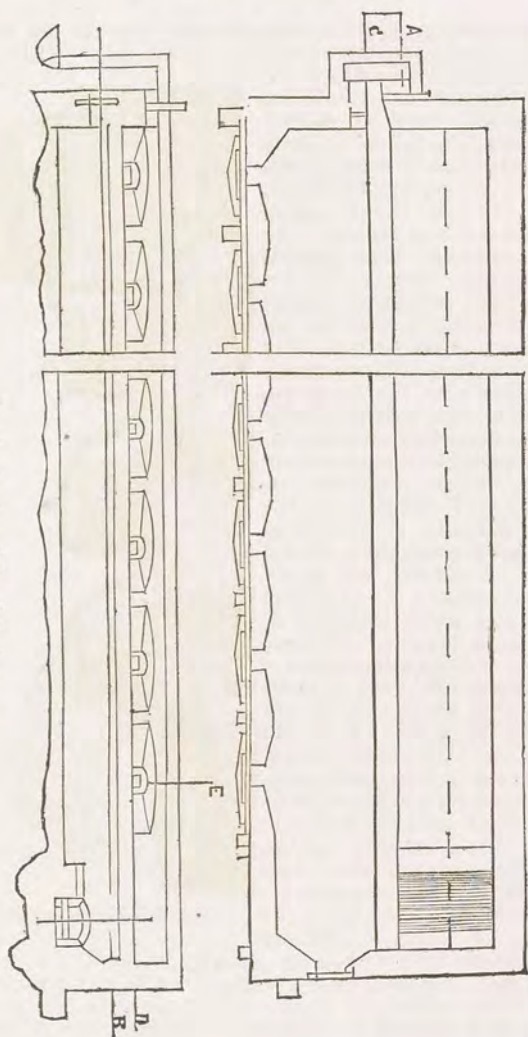


Fig. 2—Section of Desulphurizer.

commences gradually to raise, in order that the fire may be admitted at about three feet above the solution. The furnace is kept constantly full of water, in order that the leaden sides may not be melted. When nearly full of sulphate of soda, the fire is extinguished, the mother liquid removed, and the three working doors at the bottom opened. The solid and semi-fluid sulphate is discharged upon a wooden floor, and, as soon as consolidated, is placed upon the top of the furnace to dry. The dry sulphate, as above stated, is mixed with the fresh ore, ground, and used repeatedly in the desulphurization of ores. The precipitating and evaporating furnaces might be constructed of solid masonry, but the difficulty in preventing leakage through the brick, and cost of material, will nearly counterbalance the expense of the lead, which preserves at all times its value. We have given in detail a description of "Monnier's Process," and have but a few words more to add on its importance. In the old method of manufacture of sulphuric acid from pyrites containing a small amount of copper, the residue has been submitted to a smelting process. In this method water does the work, and an ore containing not more than 3 or 4 per cent. of copper (which has

heretofore been refused by smelting works in this country can be successfully and profitably treated. A residue, with no greater content of copper than above given, and perfectly free from sulphur, is worthless to smelting establishments in

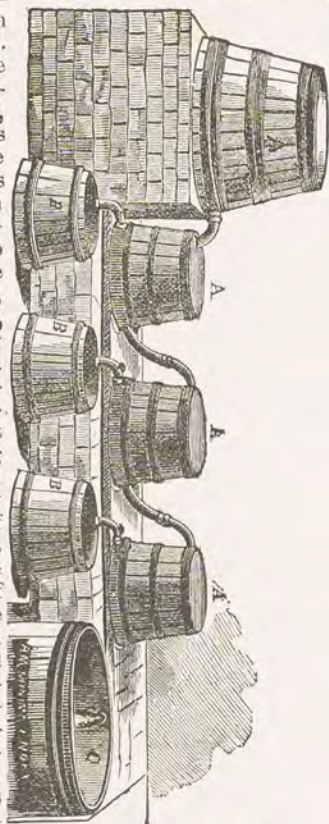


Fig. 3.—Lixiviating Tubs.

his country; but by the application of the process we have described, the whole is extracted by water at but small cost, saving concentration and waste of ore, and enabling mines scattered over the country now considered valueless to become profitable and dividend paying. If we have been correct in our position that the Colorado and other auriferous minerals require only desulphurization to improve the status of most of the explorations in the sections where they are extracted, it must at once be evident that in the employment of this process (the value of which is demonstrated by operations on an extended scale), the producers of such a mineral have the key to complete success. The facility and cheapness with which it can be used permits of its application in those sections where the more expensive smelting processes proper are entirely impracticable; the thoroughness of its desulphurization leaves nothing to be desired, and the small cost of the requisite apparatus will permit of its use by the pioneers of mining countries possessed of but small means.

Fig. 72 is a representation of Bruckner's furnace for roasting ores. It consists of an iron cylinder suspended by chains, which in rotating mixes and stirs the ore by

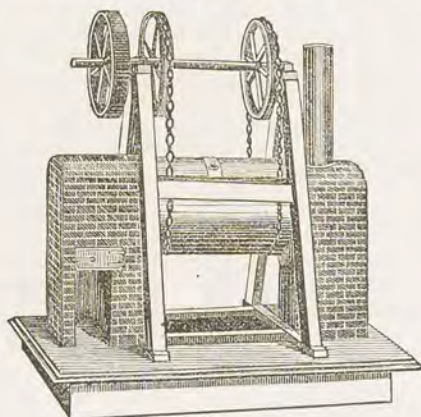


Fig. 72.

an internal apparatus. The inventor states that the furnace, which is portable and can be carried on muleback, is made of two sizes—one nine feet long, and holding fourteen hundred pounds of ore, and the other six feet long, and holding eight hundred pounds. These two sizes require respectively one-horse power and three fourths of one-horse power to drive them.

Figs. 73 and 74 represent two forms of Wheeler & Randall's tractory grinders and amalgamators. The principal peculiarity of these is the form of the mullers, described by the inventors as a "tractory conoid surface." They state the advantages of this form as follows:

"The relative grinding capacities of the grinder and amalgamator, of the flat-bottomed pan, and of the conical pan *when properly constructed*, are respectively 177, 98, and 110.

"That is, the respective mullers being of the same di-

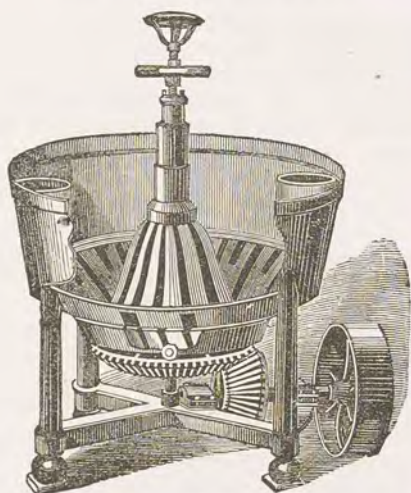


Fig. 73.

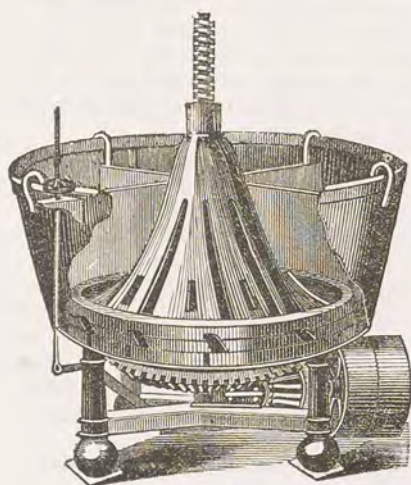


Fig. 74.

ameter, same weight, same hardness, and running at the same velocity, the grinder and amalgamator will reduce one hundred and seventy-seven tons of ore, the flat-bottomed pan ninety-eight tons, and the conical pan one hundred and ten tons to the same degree of fineness in the same time.

"The wear to the shoes and dies at their grinding surfaces in the grinder and amalgamator is perfectly uniform, thus securing evenness of reduction to the pulp, as well as steadiness of motion to the muller. Uniform wear of the grinding-plates has been attained in no other than that of the tractory form—nor can it be.

"Another property of excellence in this machine is that the metal or substance to be amalgamated passes *direct* from the grinding surfaces into the quicksilver; thus excluding the possibility of its becoming coated with any foreign substances after having been burnished.

"Those using this invention certify that they thoroughly reduce five tons of ore, as it ordinarily comes from the wet battery, per day in each pan, four feet diameter, the muller making sixty-five revolutions per minute."

A secondary object is gained in these pans, by the employment of open mullers, whereby the pulp is more readily and repeatedly subjected to the action of the grinding surfaces than has hitherto been obtained by the disk-formed mullers.

In Fig. 73 the bulk of the quicksilver remains nearer the center of the pan, and consequently more quiescent; while in Fig. 74 it is found at the circumference, where it is more agitated; but, on the other hand, by the action of the mullers in this pan, the pulp, and with it the gold, is thrown violently, by centrifugal force, directly into the body of the quicksilver, with a greater certainty of being retained there. The opinion of miners being somewhat divided as to the efficiency of these two modes of amalgamation, they have here their choice of manner, while the same degree of grinding efficiency is presented in both.

Fig. 73 represents the pan with the greater base of the

conoid or grinding surface upward, while Fig. 74 represents the greater base downward.

The following illustrations, remarks, and descriptions exhibit the construction and operation of the machinery used by the "Bullock Ore-Dressing Machine Company."

The theory of Bullock's process for dressing mineral ores is as follows:

First. To reduce the ore to an *impalpable powder in water*.

Second. To submit the ground ore to the action of such chemical agents as will decompose the whole mass in a wet state.

Third. To amalgamate the metallic gold and silver with quicksilver in a wet state.

Fourth. To collect the non-metallic gold and silver by the use of electricity.

The practical operation is as follows:

First. The mechanical division of the mineral ore into infinitesimal atoms in water by means of the Bullock quartz-cracker, or crusher, or pulverizer.

Second. The chemical decomposition of the ground ore whilst the same is held in suspension in a liquid heated by the injection of steam to two hundred degrees Fahrenheit. In this condition the chemical agent is brought into immediate contact with *every atom* of matter contained in the tub, and, as a matter of course, immediate decomposition ensues in the Bullock decomposing-tub.

Third. The amalgamation of the metallic gold and silver with the quicksilver produced by the mechanical action of the Bullock improved amalgamating pan in combination with a galvanic battery.

Fourth. The electro-chemical amalgamation of the *non-metallic* gold and silver contained in the wash-water used in the manipulation of the ores, as above stated, by means of the Bullock electro-chemical amalgamator.

Fifth. The mechanical separation of the amalgam from the gangue and waste by the use of the Bullock shaking-table.

First in order we give a cut and description of the cracker.

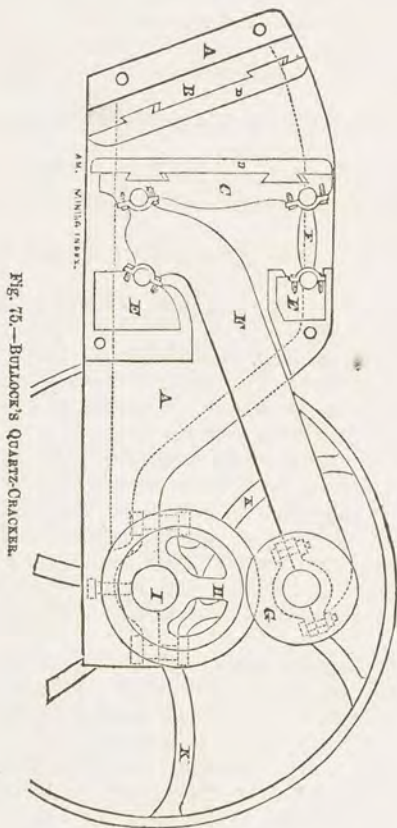


Fig. 15.—BULLER'S QUARTZ-CRACKER.

LETTERS OF REFERENCE.

A A, side-plate. *B*, adjustable jaw, with wearing-plate. *C*, movable jaw, with wearing-plate. *D D*,

wearing-plates. *EE*, cross-bars. *FF*, levers. *G*, friction-roller. *H*, excentric. *I*, shaft. *K*, driving-pulley.

The Bullock improved quartz-cracker, or rock-breaker, as shown by the engraving, is peculiar in its movement, that is, the movable jaw is so adjusted as to receive the same forward and downward movement at the top as at the bottom of the jaw, and thus all parts of the jaw are moved with equal force against the rock. At the same time, by a change in the length of one or both of the levers, more or less motion, and of course, more or less force, may be given to the top or bottom, as it may be required to meet any condition that may arise, and that at a very trifling expense. The jaws may be adjusted in a moment so as to discharge the rock the size of nuts, or in a fine dust. The cost, power, and capacity of this cracker are in proportion to its size and the amount of power applied to work it. When used in connection with the Bullock crusher or pulverizer, it is simply run fast enough to crack quartz sufficient to keep the mill supplied, which requires very little power—not one-horse; when run separate from any other machine, it may be driven at a high speed and will do an immense amount of work. They claim that it will do more work with a given amount of power, in a given time, than any other machine now in use. This machine, when attached to the Bullock crusher or pulverizer, drops the broken quartz directly into the water in the trough, and thus saves handling the broken quartz, and avoids all dust or waste of quartz or gold. When it is worked independent of any other machine, the jaw may be set up close and a large portion of the quartz crushed to a powder in passing once through the mill, either wet or dry, and at the rate of from ten to fifty tons per day, according to the size of the mill and the amount of power applied.

Next in order is the crusher, Figs. 76 and 77.

A A are two bed-timbers upon which all the stationary parts of the mill are erected. *B* is one bed-timber upon which the movable parts of the mill are erected. *C C* are cast-iron stands or pillow-blocks fitted with

journal-boxes at top. *D* is a cast-iron circular trough or basin. *E* is a bevel-wheel. *F* is a bevel-pinion. *G G* are two crushing-wheels. *H* is the main shaft. *I* is the

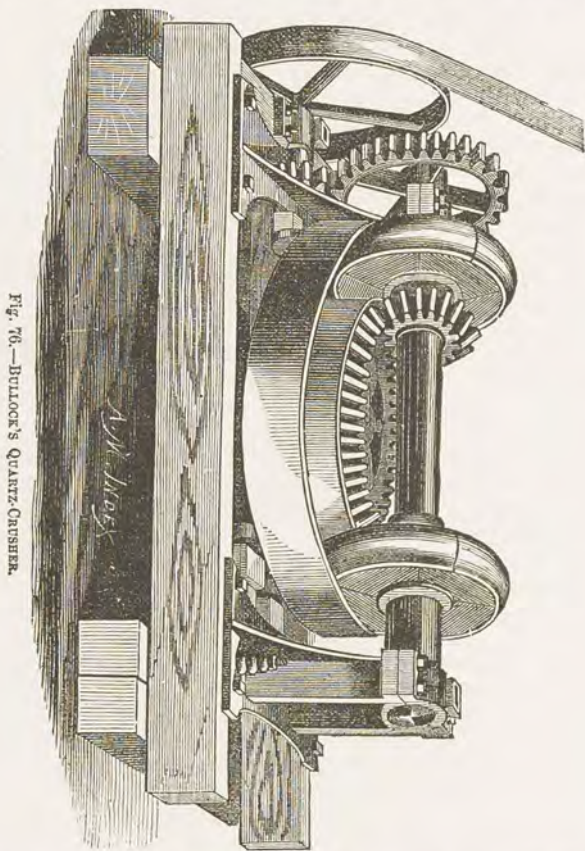


Fig. 76.—BULLCOCK'S QUARTZ CRUSHER.

driving-pulley. *J J* are anti-friction rollers. *U U* are cast-iron bed-plates. *K K K K* are journal-boxes for

rollers. *L L* are bolts for springs. *M M* are rubber springs. *N* is the centre-pin and stand. *O O* are two rock-shafts. *P* is a cast-iron sleeve. *Q* is a spur-wheel

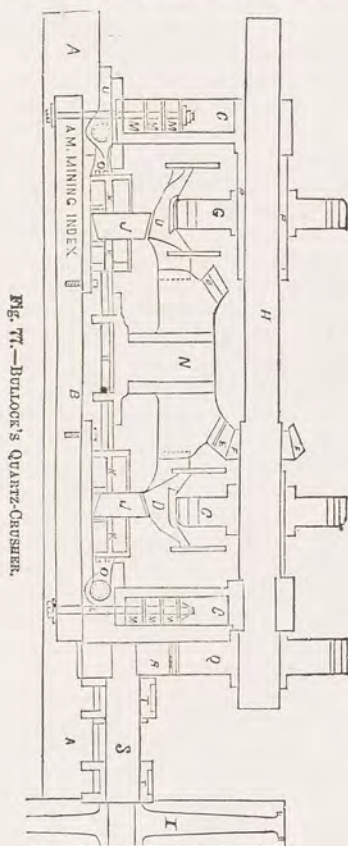


Fig. 77.—BULLCOCK'S QUARTZ-CRUSHER.

on main shaft. *R* is a pinion on counter-shaft. *S* is the counter-shaft. *T T* are journal-boxes for counter-shaft.

The mechanical construction of the Bullock quartz-crusher, or pulverizer, is based upon the theory that the quartz should be reduced to a powder in water, and retained in that condition in the mill during the pleasure of the operator; that, to do this, it should be pressed between two smooth, hard surfaces with a sliding motion whilst under the pressure, so as to produce a crushing and grinding by abrasion of the broken quartz within itself; that the quartz must be subjected to these grinding surfaces repeatedly, alternately grinding and washing out the powder, until the whole of the rock is reduced and discharged from the mill as fine as desired. That this alternate grinding and washing should be without handling the quartz or screening it at all. That the grinding should be done uniformly, rapidly, and with the least possible expense of power. That the grinding surfaces should be smooth and of such form and construction that the wear upon them will not alter their shape or effective force and capacity as long as they are retained in use. That these grinding surfaces should be so constructed as to be easily replaced when worn out, and should be adjustable and yielding, so that any thing too hard to be crushed, that might chance to come between them, would not break the mill. That the weight of the machinery should be as light as possible, consistent with perfect safety. That the water used in washing should be retained in use continually. That the feeding of the quartz into the mill and the discharge from it should be continuous; all of which, it is claimed, has been secured and scientifically combined to a very great degree of perfection, as proved by the practical operation upon hundreds of tons of quartz-rock; and it is readily admitted by all who have taken the trouble to examine it in person. But to enable others, who have not seen it in operation, to judge for themselves to some extent whether it is so, we will here give the

MODUS OPERANDI.

Attach the pulley, *I*, to the motive power through the medium of a belt, so as to cause the shaft, *H*, to revolve

forty times per minute; this sets the whole mill in operation. The ores to be crushed may now be fed into the trough, *D*, at any convenient point, which will be carried immediately under the wheels, *G G*, by the rotation of the trough, where they will be crushed. A constant supply of water must be run into the trough whilst the crushing is going on, and the ground quartz drawn off with the water by means of siphons; this feeding and drawing off may continue *ad libitum*. By the springs upon the bolts, *L L*, any pressure desired may be brought upon the trough to press it against the crushing-wheels, and at the same time allow any substance which may be too hard to be crushed to pass through without breaking the mill. The springs also accommodate the trough to the wear of the wheels, or to any unevenness that may occur in the trough from irregular feeding. The lugs attached to the trough, *D*, are slotted vertically, so as to admit the points of the arms of the wheel, *E*, and allow the same to pass up and down freely. The relative diameters of the gear-wheels, *E* and *F*, the crushing-wheels, *G G*, and the trough, *D*, are such as to cause a rubbing or slipping of the crushing-wheels, *G G*, upon the inside bottom of the trough, *D*, by which the effective crushing power is greatly increased. The rock-shafts, *O O*, prevent the bed-timber, *B*, from tipping or canting sidewise, and this keeps the trough, *D*, in proper position when in use or working, and at the same time allows each end of the bed-timber, *B*, to move up and down freely and independently of the other. The centers of the gear-wheels being immovable, the teeth of the wheels are always in mesh at the proper point of contact, whilst the trough moves up and down to accommodate itself to whatever is passing between it and the crushing-wheels, and at the same time the trough is compelled by the slotted lugs, in connection with the points of the arms of the wheel, *E*, to rotate with it and thereby cause a rubbing or slipping between the crushing-wheels, *G G*, and trough, *D*. The connection binding the crushing-wheels, *G G*, and the trough, *D*, together, being adjustable and elastic, avoids the necessity of great weight in the crushing-wheels.

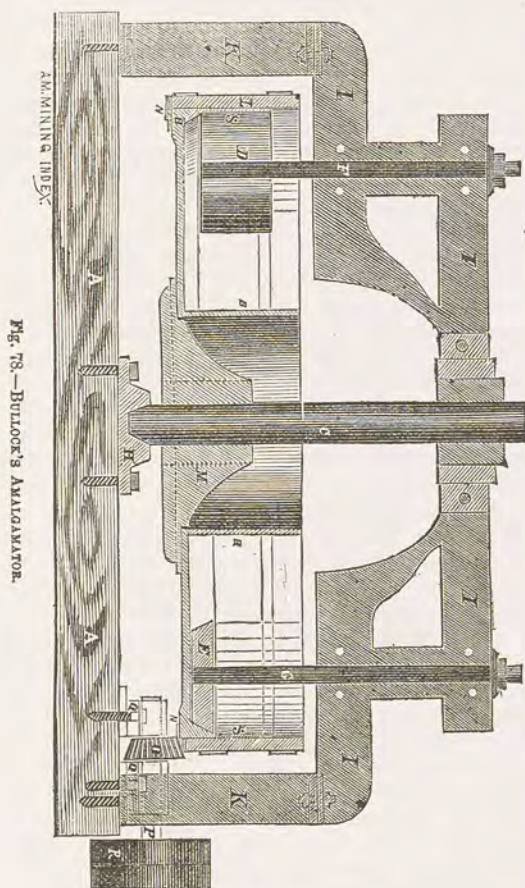
Next in order is the decomposing apparatus to which all the ground ores containing foreign substances, that prevent an amalgamation of the gold and silver with the quicksilver, must be transferred for chemical treatment.

The peculiar construction of the decomposing tub is a matter of no sort of consequence, a tub, tank, or trough, either, will answer equally well; the only important part is so to arrange it that the contents may be conveniently and sufficiently agitated to hold the particles of matter, in the liquid contained in the vessel, in suspension, and at the same time to allow free access to the surface of the liquid for the workmen to remove such portions as may be found necessary during the process of decomposition. The chemical agents to be employed must, of course, vary, so as to agree with every change in the character of the ores. The chemical ingredient that would be proper to use for sulphides of iron would not be proper to use for carbonate of copper or chlorides of silver. Therefore, the agent required must be determined by the analysis of a small lot of the ore to be treated in the decomposing tub.

Next in order is the amalgamator, to which the decomposed ore must be transferred for amalgamation of the precious metals with the quicksilver.

The mechanical construction of the Bullock amalgamating pan is based upon the theory that the ground ores contain a large percentage of the metals in a very minute state of division—imperceptible dust; that it is held mechanically in the gangue or ground ore, and, when mixed in water, is held in suspension, notwithstanding its specific gravity is much greater; that the pasty state of the ground ores prevents the quicksilver uniting with the gold without a great deal of rubbing and washing; that the ground ore should be rubbed in the quicksilver and not ground in it; that the floating gold and silver should be secured without relying upon specific gravity, whilst the precipitated gold and silver is secured by amalgamation with the quicksilver in the bottom of the pan. This theory reduced to practice is represented by

the sketch here shown, which is a vertical section through the center.



LETTERS OF REFERENCE.

A, wooden frame to support and hold the machine.
B, cast-iron pan. *C*, shaft secured to frame *I* by boxes.

D, wooden roller with an elastic jacket. *E*, plate or disk of iron. *F*, shaft to which the roller, *D*, is attached. *G*, shaft to which the plate, *E*, is attached. *H*, step-plate to receive the shaft, *C*. *II*, iron frame to support the shafts *C*, *F*, and *G*. *KK*, iron columns to support the frame, *II*. *LL*, wooden curb to the pan, *B*. *M*, center-piece to hold up the pan, *B*. *NN*, toothed segments by which the pan is made to rotate. *O*, pinion by which the pan is driven. *P*, shaft for the pinion. *Q* *Q*, boxes for the shaft *P*. *R*, pulley to drive the shaft *P*. *S*, copper plate passing around the inside of the rim, *L* *L*.

This machine is set in operation by attaching a running belt to the pulley, *R*. Some fifty pounds of quicksilver, more or less, are now put in the pan and the ground ore previously prepared for amalgamation is mixed up with water sufficient to hold it in suspension in the pan, or to simply form a paste, according to circumstances. The rotary motion of the pan gives a rotating motion to the plate, *E*, and roller, *D*; the face of the plate, *E*, being set near the bottom of the pan, by its cycloidal motion, or tracing, over the surface gives the material a rubbing or scouring as it passes under it or between it and the rim of the pan, producing a different effect from the common roller. The roller, *D*, collects the floating particles of gold or silver and of the quicksilver by its rotary motion, and presses them hard against the copper plate. The quicksilver upon the copper plate is kept clean and free from any oxyd or dirt by the continual pressure of the elastic jacket of the roller, *D*, so that all the gold, silver, copper, and quicksilver that passes between the roller and the plate becomes immediately attached to the plate in the form of amalgam, whilst the gangue and dirt is washed away by the water. The particles of gold, that are of sufficient specific gravity to precipitate to the bottom of the pan, are rubbed into the quicksilver by the plate, *E*, in the form of amalgam, while the dirt is washed away and thus a separation is effected.

The roller, *D*, and the plate, *E*, may be so arranged as to be driven by gear or blank-wheels or pulleys attached to the shafts, *F* and *G*, and to the pan, *B*, or on a wheel

prepared for the purpose and attached to the shaft, C , instead of the pan, and of such relative diameters, as to give to the roller D , and the plate, E , a greater or less speed than they would have if simply driven by friction against the pan.

The next in order is the Bullock shaking-table or wash-

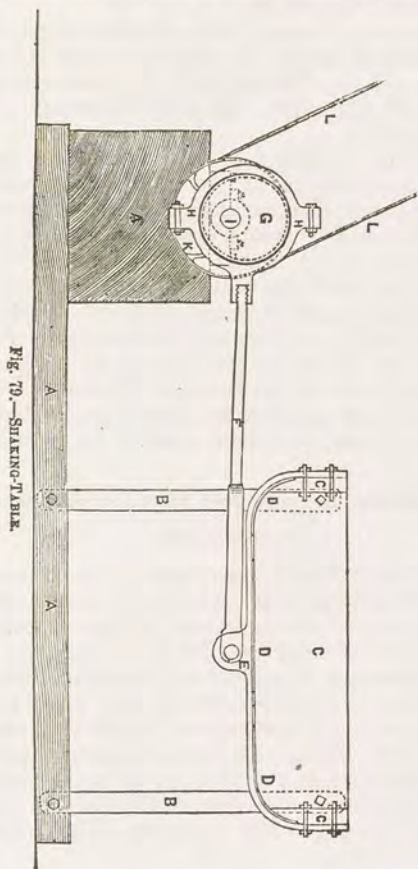


Fig. 79.—SHAKING-TABLE.

ing pan, to which all the ore and quicksilver is transferred from the amalgamator, for the purpose of separating the amalgam and the quicksilver from the waste or gangue. The mechanical construction of this machine will be readily seen and understood also upon an examination of the cut and letters of reference. The cut is a vertical section through the center.

A A is a wooden frame. *B B*, wooden sway-bars. *C C*, wooden frame of table. *D*, copper bottom of table. *E*, iron strap. *L L*, driving-belt. *F*, connecting-rod of eccentric. *G*, eccentric. *H*, eccentric-strap. *I*, shaft. *K*, driving-pulley.

The inventor of the foregoing machinery and processes has evidently given the subject of dressing mineral ores a great deal of study. We are glad to see our scientific and practical mechanics, chemists, and miners giving it so much attention, affording good grounds, as we think, to anticipate the happiest results.

A very great improvement in gold and silver amalgamation has lately been proposed and experimented upon in England, the nature of which is so well explained in the following letter to the *London Mining Journal*, and the method itself supplies so important a want in our ordinary processes, it seems worthy to be quoted *in extenso*.

Improvements in Gold and Silver Amalgamating.

BY THOMAS BELT.

"One of the difficulties met with in the extraction of gold and silver from their matrices by amalgamation is what is known amongst miners as the sickening and flouring of the mercury used for that purpose. In this state the mercury is tarnished on the surface, its amalgamating action is greatly reduced, and when triturated in the amalgamating machines it breaks up into minute particles, which will not again unite, and are carried off with the slimes, so that with many ores the loss of mercury forms a considerable item in the cost of extracting the precious metals. Mr. Crookes, F.R.S., the editor

of the *Chemical News*, has, however, recently made a discovery which promises to obviate this difficulty, and prevent this great loss, and which will make his name as well known amongst the mining public as it has long been in the scientific world for his chemical researches, and especially for his discovery of Thallium. It is, that by the simple addition of a small quantity of the metal sodium, the sickening of mercury is entirely prevented, floured mercury immediately brought together again, and the amalgamating action of ordinary mercury vastly increased. It is found that a surprisingly small amount of sodium is sufficient to effect the clearing of fouled mercury. It will require a longer series of experiments than there has yet been time to carry out, to determine the smallest effectual proportion, but it has already been proved that one twenty thousandth part of sodium, added to the mercury, is amply sufficient, so that this discovery has the great advantage of cheapness to recommend it. Sodium may even now be obtained in large quantities for five shillings per pound, and if a demand were to spring up for it, its price would be greatly reduced; but, calculating at the present price of the metal, and using the quantity that experiments have proved to be amply sufficient for any description of ore, the cost is a mere trifle, in comparison with the advantages gained. With the ordinary amalgamating troughs in gold mining, one hundred and twenty pounds of mercury are used to each set of four stamps, reducing four tons of quartz in twelve hours; and supposing the supply of sodium to be renewed every twelve hours, the cost would be less than one penny per ton of quartz treated, which would certainly be more than covered by the loss of mercury prevented, without reference to the greater quantity of gold obtained, in consequence of the improved condition of the mercury.

“Mr. Readwin, in a series of experiments at Gwyn-fyndd and Castell Carn Dochan Gold Mines, in North-Wales, has found that when sodium is added in excess, its effect is injurious instead of beneficial. Some sodium

having been placed in my hands for trial, by the discoverer of its new use, I have been able to ascertain its effect upon mercury, and also upon the different minerals usually associated with gold in lodes, and the results obtained throw considerable light upon its action, and seem to account both for its beneficial effect in small, and its prejudicial effect in large, quantities. They can, however, only be considered approximate, and more suggestive than decisive, but they are sufficient to show the great value of the use of sodium in the amalgamation of the precious metals, and indicate its probable action. The experiments were made with mercury containing one per cent of sodium.

"1. When a little of the sodium amalgam was added to ordinary mercury, the affinity of the latter for gold was greatly increased, so that when pieces of gold were dipped into it they were instantly covered with mercury, although when dipped into mercury to which no sodium had been added, amalgamation was very slow and difficult to obtain.

"2. Floured mercury immediately ran together into a single globule on the addition of a little sodium amalgam.

"3. When the iron pyrites, (bisulphuret of iron,) magnetic iron pyrites, (sulphuret of iron,) or copper pyrites, (sulphuret of copper and iron,) were triturated with sodium amalgam, the pyrites were decomposed, and on the addition of water, a black precipitate of sulphuret of iron was obtained.

"4. Triturated with sodium amalgam: *a.* Arsenical pyrites were decomposed and arsenic amalgam formed; *b.* Galena (sulphuret of lead) was decomposed, and lead amalgam formed; *c.* Blende (sulphuret of zinc) was decomposed, and zinc amalgam formed; *d.* Litharge (oxyd of lead) and white lead (carbonate of lead) were decomposed, and lead amalgam formed.

"From these experiments it appears that sodium amalgam has an energetic action upon both the oxyds and sulphurets, reducing both; and as the sickening and flouring of mercury is supposed to be due to the forma-

tion of the protoxyd and the sulphuret of mercury, its beneficial effect appears to lie in the reduction of these; but if added in excess, it will, after effecting this operation, attack the ores of the baser metals, and with many of them form amalgams. The mercury then becomes loaded with the baser metals, and its action upon silver and gold is greatly reduced. When arsenical pyrites is contained in the ore treated, the arsenic amalgam formed by the action of the excess of sodium floats on the surface of the mercury, and prevents the gold from coming in contact with it. It is thus seen that only sufficient sodium should be added to reduce any mineralized mercury, and to keep it in an efficient state. The quantity added, and the duration of its effect, will vary with different kinds of ore treated, as it is well known that some minerals sicken and flour the mercury much more quickly than others. The whole question of the fouling of mercury when used for amalgamation requires a much more careful chemical examination than it has yet received, and it is a matter of great importance to miners that the attention of so able a chemist as Mr. Crookes has been directed to the subject. Already a discovery of unquestionably great value has been made, which will soon be taken advantage of wherever gold is extracted from its matrix, and we can only hope that the discoverer will participate largely in the profits which will be realized by the use of his discovery."

Fig. 80 is an external view of Blake's patent rock-breaker, which has proved very efficient in breaking iron, copper, gold, silver, and lead ores, as well as for breaking stones for roads and other similar purposes. The ore is introduced at the opening above *A*, one side of which is formed by a heavy fixed block of iron with a corrugated surface, while the other side is formed by a movable jaw suspended from the bearings seen on the left of the engraving. This jaw is set so as to render the space at the bottom of the hopper thus formed much narrower than above, and at every revolution of the machine the lower end of this jaw is advanced about one fourth of an inch toward the fixed jaw by means of a lever

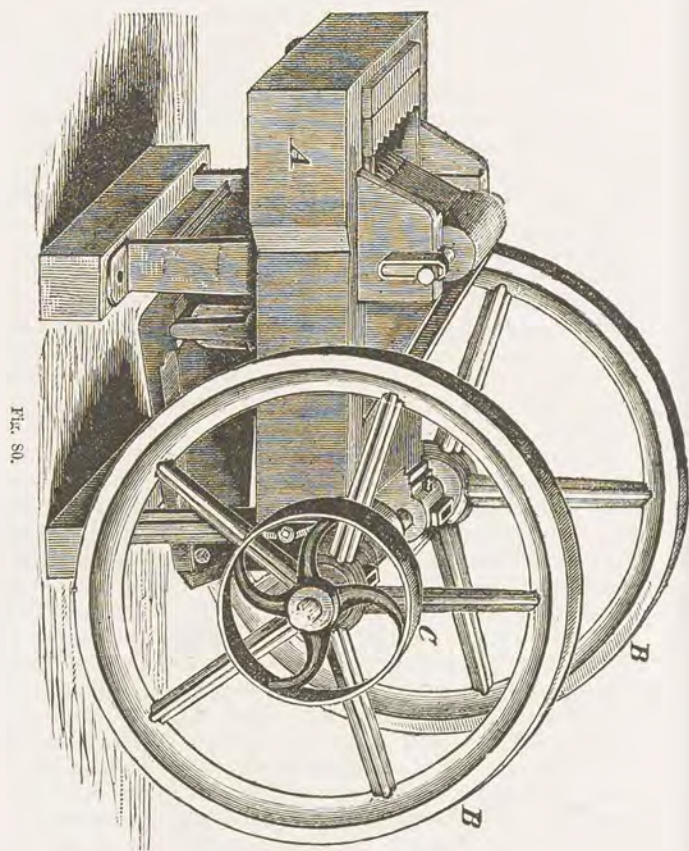


FIG. 80.

acting upon a powerful toggle-joint. Hence, if a piece of rock is dropped between the convergent faces of the jaws, it will be gradually reduced to the size at which they are set at their lower extremities.

HUGHES'S ATMOSPHERIC OR LIGHTNING ORE STAMP.

This machine, for the reduction of gold and silver ores to an impalpable powder, is very simple in construction, little liable to get out of repair, and easily repaired by an ordinary mechanic when necessary. The stamp used is but seventy-five pounds weight, yet by atmospheric pressure the inventor claims that it strikes a four thousand pound blow, with the average rapidity of two hundred blows per minute, or four hundred with the two stamps that are used in the machine illustrated. The piston (and stamp-head) is raised by a double cam on the main shaft, alternating the blows, which the patentee considers equivalent to a balance-wheel. It is thus raised, with a valve on the top of it, into an atmospheric chamber, thereby creating a vacuum under the valve, which gives such great momentum to the stamp when relieved from the upward motion of the cams as to produce the results above mentioned. The principle upon which it is constructed can be seen at a glance. The same principle can be applied as easily to any number of stamps as to two, and with equal facility it can be applied to the stamp-mills now in general use. Most practical mill-men are firm in the conviction that the stamp system of reduction can never be bettered, and therefore never superseded. But, as at present constructed, they are large, costly, cumbersome, and difficult of transportation. Where mines are far from the seaboard, it often will not pay to transport such mills. If then a small, compact, portable mill can be found that will do as much work and be infinitely less expensive as to cost of transportation, erection, wear and tear, running, etc., certainly it must prove a great desideratum.

E, atmospheric chamber or barrel causing vacuum.
L, air-valve for supply and vacuum. *I*, stamp-head or

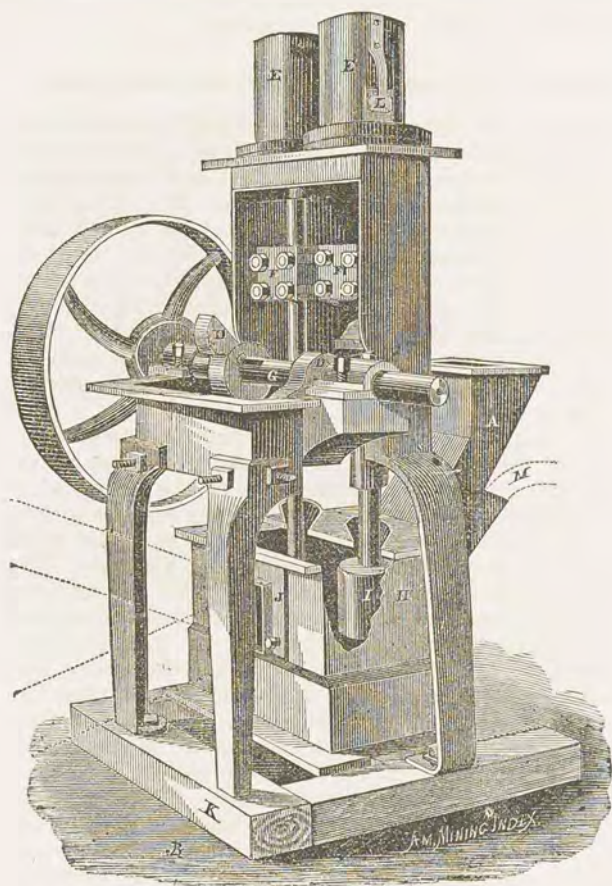


Fig. 81.

shoe, (weight seventy-five pounds,) piston included. *D*, cams on main shaft to raise the stamps. *F*, piston-guides. *G*, main shaft. *A*, feed-box. *M*, air-blast from fan-blower to remove the ores as fast as reduced. *J*, plate upon which is secured the outlet-pipe to receiving-box. *H*, mortar with dies inside. *K*, strong wooden frame.

NOTE.—There is also a leather cushion between the upper and lower pistons. The outlet pipe for dry crushing is shown by dotted lines running diagonally upward, and for wet crushing, downward.

Fig. 82 represents a machine formerly employed to a considerable extent in California for gold-washing. It is the invention of Mr. James Patterson, of Placerville, and is called the *guyaskutus*. The large stones roll over the end, while the dirt, gold and water pass through a tom-iron into the machine, where the gold is separated

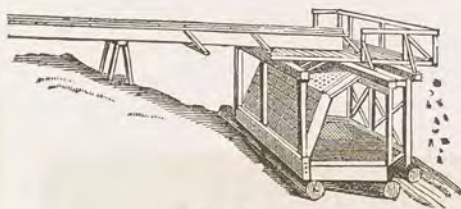


Fig. 82.

by being passed over the surface of amalgamated copper plates forming the side of the machine, and by washing over patent riffles.

Fig. 83 represents the furnace employed at the New-Almaden mines for the extraction of quicksilver. It is built of bricks, of a size to hold from sixty thousand to one hundred and ten thousand pounds of ore, according to its character. The chambers are fired from a lateral furnace, fed with wood, and separated from the ore by a wall pierced with numerous openings, formed by leaving out a brick at intervals. Connected with the furnace is a series of lofty and capacious chambers, also of mason-

ry, through which the whole product of combustion is compelled to pass alternately above and below, from chamber to chamber, until all the available mercury is condensed. The draft from these furnaces is carried by inclined stacks up to the top of a lofty hill several hundred feet distant, and here the sulphurous acid and other effete products of the furnace are discharged. Formerly, no precautions were taken to prevent the escape of mercury through the foundations of the furnace to the earth beneath; now, the furnaces stand upon double arches of brickwork, and plates of iron are built into the founda-

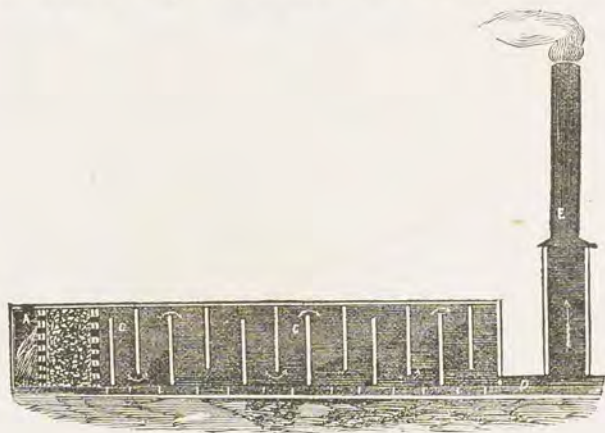


Fig. 83.

tions, so as to cut off entirely all descending particles of metal and turn them inward. The only preparation which the ores undergo, preparatory to reduction, consists of hand-breaking or "cobbing" for the removal of the unproductive rock. The small ores and dirt hoisted from the mine are made into "adobes," or sun-dried bricks, sufficient clay for the purpose being associated with the ore. The object of these "adobes" is to build up the mouths of the furnaces to sustain the load of

richer ores. No flux is employed, there being sufficient lime associated with the ores to aid the decomposition of the sulphurets. The whole process of reduction is extremely simple, the time occupied from one charge to another being usually about seven days. The metal begins to run in from four to six hours after the fires are lighted, and in about sixty hours the process is completed. The metal is conducted through various condensing chambers, by means of pipes of iron, to a "crane-neck," which discharges it into capacious kettles. It undergoes no further preparation for market, being quite clear from all dross.

Fig. 84 represents the concentrator of M. Victor Barron. The ore is introduced into the hopper seen on the left of the engraving, whence it passes into an inclined trough (a part of which is shown by the removal of a portion of the side) along the sides of which, a little above the bottom, rows of slots are made. This trough, which works under the surface of the water, filling the body of the machine, has a slight vibrating motion lengthwise of the machine and a much slower rocking motion. By these combined movements the ore is kept in continual agitation, the lightest parts, which are quite free from ore, pass through the slots near the head of the trough; the portions which still retain some small amount of ore pass out farther down, and are collected in a second compartment of the bottom, while the rich ore traverses the entire trough and falls into the last compartment of the bottom, whence it is discharged at pleasure by means of the weighted valve shown at the right of the figure. By means of adjusting screws the inclination of the trough, as well as the force and extent of the vibratory and rocking motions, can be regulated with the greatest delicacy, so as to adapt it to ores of different character.

Fig. 85 illustrates a machine for raising ores, men, etc., from mines by pneumatic pressure, which has been employed in some of the English mines. The ore, etc., is placed in the vessel, *A*, (seen at the bottom of the figure and on a larger scale in the center,) which slides almost air-tight in the cylinder, *C*. An air-pump, *B*,

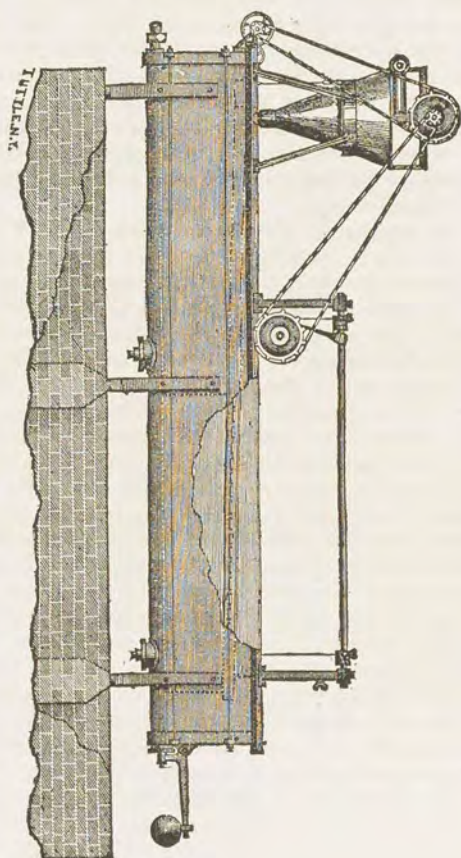


FIG. 84.

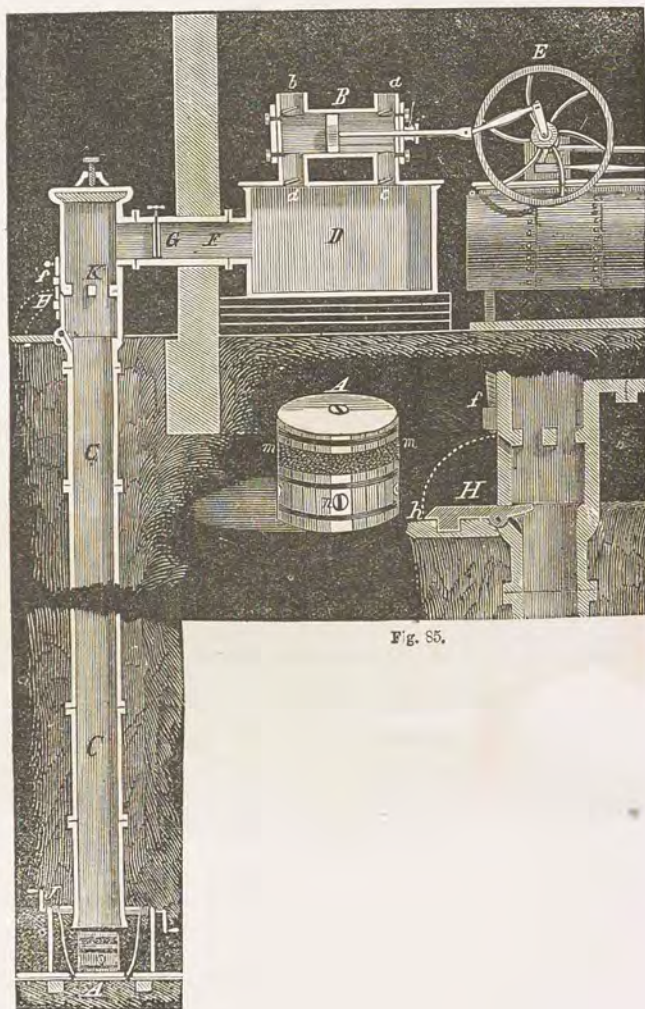


Fig. 85.

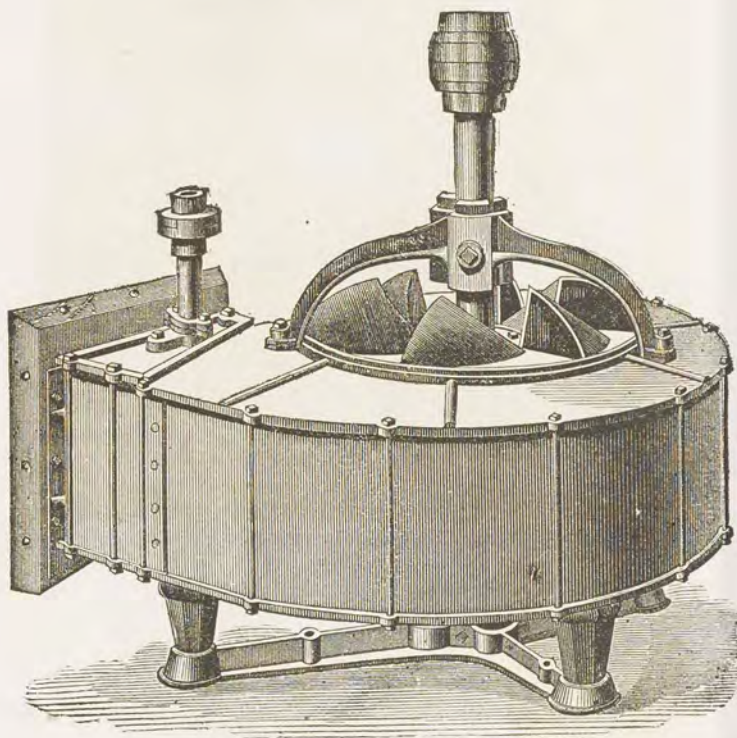


Fig. 86.

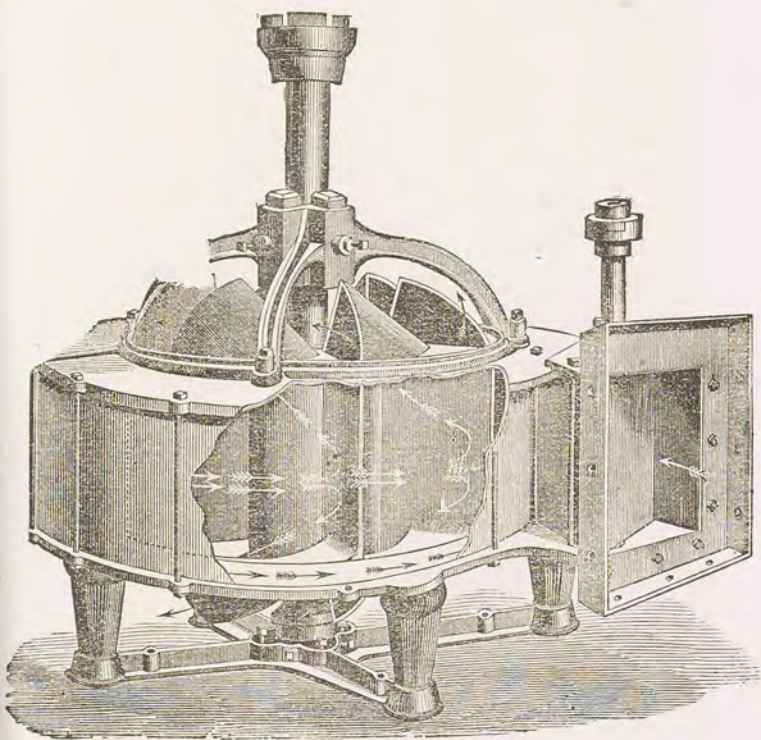


Fig 87.

exhausts the air from the receiver, *D*, which communicates with the cylinder, *C*, by means of a slide-valve at *G*. When the air is exhausted in the receiver, and the valve is opened, the ore-vessel, *A*, is driven up by the pressure of the air, and is arrested by the projections at *K*, and is removed by means of the door, *H*, which can be shut air-tight. The arrangement of this part of the machine is shown on a larger scale in the right-hand figure, which represents the door as opened and resting on the platform.

Figs. 86 and 87 represent Reynolds's improved turbine, which seems well calculated for use in mining districts where a great head of water can be obtained, even though the quantity is but small. The following extracts from the full description of the turbine will point out its chief peculiarities.

"Fig. 86 is an outside view of the case, showing also the top of the wheel, with the shaft and journal-box. Fig. 87 is a view from the opposite side, with the case broken open, to show the wheel.

"The revolving part, shown in Fig. 87, is a casting in one piece, which requires only a little lathe-work to finish it; and the stationary case and its supports are made of a few parts, likewise requiring only a little finish by the lathe. The bottom step, on which the cupped end of the shaft turns, is of *lignum vitæ*, and rests on a pedestal which is adjustable by set-screws; and the top journal has wood linings, also adjustable by set-screws. The gate is hung on its center, and accurately fitted to prevent leakage. The water, as it is constrained by the case to go nearer the center, acts directly upon the partitions; after which, it turns, and issues from the openings in the top and bottom of the wheel; and, in issuing, it reacts, on the principle common to turbines. The peculiar shape of the discharge openings is such as to give the most favorable velocity to the water at the parts farthest from and nearest to the shaft.

"Compared with other turbines, this is found easier to keep in order. It has a free delivery, and is not

choked by small bodies. And all parts that require attention are accessible without breaking any joint."

Fig. 88 represents two kinds of miner's picks, manufactured by the "Washoe Tool Manufacturing Company."

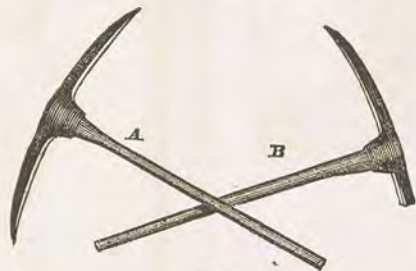


Fig. 88.

Fig. 89 shows a pan intended for dry-washing. In this operation, which is only practiced with sands of great richness and when no water can be obtained, the



Fig. 89.

sand is lifted up and poured from some height into the pan, in a place where a pretty good breeze is blowing. The sand is thus winnowed away while the grains of gold fall back into the pan, and by a repetition of this operation the gold may be obtained nearly pure. In the pan represented, a little mercury is placed at the bottom, and aids in collecting the gold. When the separation is concluded, the mercury is discharged by the opening at the bottom, which is closed by a screw, shown in the figure.

Fig. 90 represents Leschot's annular diamond drill, which has lately been introduced into this country, and seems to promise results of considerable value.

In 1860, M. Rodolph Leschot, a civil engineer of Geneva, Switzerland, resident in Paris, undertook a series of experiments for the purpose of discovering some method of perforating rock with more rapidity than can be accomplished in the usual method by percussion. He

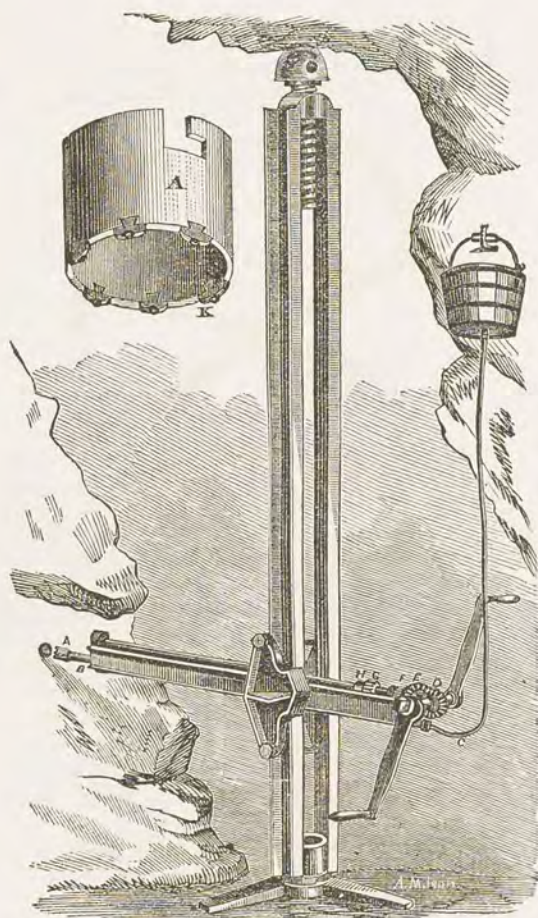


Fig. 90.

put to the test all the hard metals and stones that promised favorable results, and found *the diamond* the only substance with which he could arm his cutting tool so as

to enable him to attack the hardest rocks, like granite and porphyry, with success. This he proved to the satisfaction of French engineers, and a machine working on his system was introduced into a tunnel at Pistoia, in Italy, on the railway running from Pistoia to Bologna.

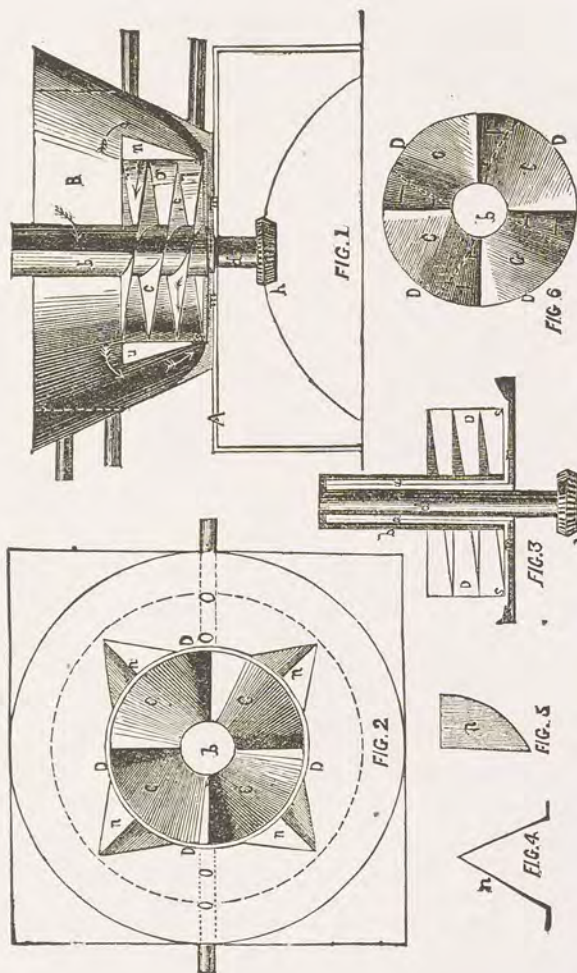
The operation of the diamond drill is simple, and the following general description will suffice for the reader. The illustration presents the drill as employed for tunneling. Fig. *A* represents an enlarged view of the construction of the drill, with the diamonds, *K*, soldered in a dovetailed plug, which is set alternately to the outer and inner peripheries. The frame consists of two wrought-iron uprights, in the top end of which may be seen the screw, having lever-holes by which this frame may be held or fastened to the top of the tunnel, and the whole may be readily removed by one or two operatives. The guide-frame of the drill is held by bolts in said uprights, so that it may be adjusted to any angle.

The drill, *A*, is fitted to the cylinder, *B*; this cylinder is hollow. As seen in the illustration, the hose, *C*, communicates with a vessel containing water, and is coupled with said cylinder, and thus sufficient water is constantly introduced during the operation to remove or rinse the cavity of refuse material occasioned by the abrasion of the drill. In the illustration the drill, as will be seen, is a hand implement; but any kind of motive power may be attached, requiring but very little power to operate the same. The pinion, *F*, and the cog-wheel, *E*, upon another cylinder, are seen immediately over the drill and cylinder, *B*. The mitred wheel, *E*, receives its motion from the crank gear-wheel. The pinion, *F*, moves the pinion in the cylinder, *B*, (not seen in the illustration.) Said cylinder, *B*, is a threaded screw, and the adjustable collar, *H*, and pinion thus placed upon the upper cylinder move the cylinder, *B*. The threaded screw works in a movable collar, on which latter a slot is provided, wherein the stationary pinion, *H*, and a part of the pinion, *G*, is held by a pin attached to its lower end. The drill moves forward by means of this screw, and is self-feeding; it may be altered as to motion, according to

the hardness or softness of the rock material to be operated, by merely changing extra gear-wheels provided. The drill will make a cavity of uniform size, symmetrically true, of any distance.

An important attachment, highly advantageous for blasting tunnels, accompanies this drill, namely, a tool for drilling a chamber at the desired point, so that an extra amount of force may be imparted to the powder or other explosive material.

Should the drill require renewing, the cost of re-setting the diamonds, so as to present new points, and the consequent slight loss in weight, constitute the entire expense.



GASTON'S AMALGAMATOR.

HENRY A. GASTON'S NEW AMALGAMATOR.

In the accompanying drawings, Figure 1 is a central vertical section; Figure 2 is a plan or top view; Figure 3 is a detached central vertical section, showing the construction of the central portion of the apparatus; Figure 5 is a vertical section of one of the inclined partitions; Figure 5 is a side view of one of the inclined partitions; and Figure 6 shows the bottom of a four-threaded rotating screw with shoes (concave in front and rear) attached. Similar letters or reference indicate corresponding parts in all the figures. This invention is designed for grinding the pulp of metallic ores and for facilitating the process of amalgamating, by which the precious metals are separated therefrom. It consists in a rotary screw operating in connection with a core or cylinder surrounding the said screw, and placed within the ordinary amalgamating pan in such a way that when the screw is rotated in one direction it will grind or mix the pulp, or reduced ore, with the quicksilver placed in the bottom of the pan, and carrying both pulp and quicksilver up, along the flanges of the screws, through and over the top of the cylinder, thence to pass down on the outside of the cylinder, to enter again to the screw through open spaces at the bottom of the cylinder. When the screw is rotated in the opposite direction, it produces contrary currents, taking the pulp down the flanges of the screw, *collecting the quicksilver and amalgam* at the bottom and periphery of the cylinder, and forcing the entire body of the pulp into contact with and through the quicksilver. Between the cylinder and the sides of the pan are partitions with sloping sides to insure the proper passage of the ore or pulp from the amalgamating pan into said cylinder. To enable the skilled to understand the construction and operation of my amalgamator, we will attempt to describe it with reference to the engraving. A is any foundation upon which is supported the amalgamating pan, B, which is of the ordinary construction, with its sides sloping inward at the bottom, but whose sides may be vertical from the

height of the cylinder D upward. The pan is provided with suitable steam, inlet and outlet pipes, and a false bottom or dies, M, in the usual manner. C is the rotating screw, the axis of which is arranged vertically in the centre of the pan B, and which may have two, three, or four separate threads. To prevent water or grit from penetrating between the shaft of the screw and its bearing, the shaft is made in the form of a tube, or hollow cylinder, B, closed at the top but open at the bottom, as clearly shown in Figure 3, and placed, like a cap, over a fixed tube, R, which extends vertically upward from the centre of the bottom of the pan B. Firmly secured to and extending downward from the closed upper end of the hollow shaft B, is an internal shaft, A, which projects downward through the tubular stem, R, below the bottom of the pan B, and has a bevel gear, H, upon its lower end, through which motion may be communicated to the screw C, by any suitable means. If preferred the screw may be rotated by gearing applied directly to the upper end of its shaft, thus dispensing with the tube R. D is the cylinder or case surrounding the screw C, and firmly secured to the bottom of the pan. This case or cylinder, D, may be made of either wood or metal, and is provided around its lower edge at suitable distances apart, with holes, S, (equal each in size to the space between the flanges of the screw,) through which the ore or pulp passes from the pan B into the case D, or *vice versa*, as required by the operation of the machine, as will be presently explained. Between the holes S, partitions, N, are placed extending from the base of the cylinder D, at the holes S, to the top of the cylinder, and thence across to the sides of the pan B, the sides of said partitions sloping as shown at Figures 4 and 5, so that their bases occupy the entire space between the holes, thus causing the pulp, as it descends between them, to be directed toward and into the spaces S. The height of the cylinder should be one fourth the height of the pan, and the coil of the threads of the screw extends not more than one third of the circumference of the circle of which it forms a part. The opera-

tion of the amalgamator is as follows: The pan B is filled up to as great a depth as desirable with ore, which has been crushed or pulverized by any of the ordinary means, and mixed with water to any desired consistency. The screw C is rotated in the direction shown by the arrow in Fig. 1, and forces the pulp downward through the cylinder and between the flanges of the screws under the shoes attached to the base of the flanges, into contact with the dies or false bottom of the pan M, the shoes of the screw grinding and rubbing the pulp upon the said dies or false bottom M, and reducing it to a suitable condition for the introduction of quicksilver. When quicksilver has been introduced into the pan, the motion of the screw is reversed, upon which, instead of forcing the pulp downward and grinding or brightening it as above described, it forces both the pulp and quicksilver upward through the cylinder D, the pulp entering the said cylinder at the bottom through the holes S, and, passing out over the top of the cylinder, is conducted back to the said hole S by the inclined or sloping sides of the partitions N, and the sloping or curved sides of the pan, so that a continued circulation of the pulp, carrying with it particles of quicksilver, is maintained, while the large portions of the quicksilver are carried up on the surfaces of the screw-threads, thereby presenting a large surface to the circulating pulp. The operation is continued until the amalgamation of the metals contained in the ore has been completed so far as desired, when the rotation of the screw is again reversed for the purpose of collecting the quicksilver and amalgam at the bottom of the pan.

ASSAYING.

PRINCIPLES OF THE BLOW-PIPE.

The first of the following figures represents the simplest kind of blow-pipe. It is merely a bent, tapering tube of brass, from seven to ten inches long, with a minute aperture at its smaller end. It is used to concentrate to a point the flame of a lamp or candle; and this is done by blowing through it while the smaller end is just within the flame.



Fig. 91.

After blowing awhile, the moisture of the breath often condenses in the tube; and to receive this moisture, and prevent its passing out at the beak, the chamber at *I* (see Fig. 91) is usually added. The point, *b*, (seen enlarged at *a*,) screws off, and is made of platinum, in order that it may be cleaned when necessary by immersion in an acid.

When the blow-pipe is made of brass, it is usual to have an ivory mouth-piece, as it is more agreeable in the mouth. Silver is the best material; and the point, at all events, should be of platinum. Wollaston contrived a convenient pocket instrument on the plan of a common pencil-case.

Operations with the blow-pipe often require an uninterrupted heat for a considerable length of time, and always longer than a single breath of the operator. It is therefore requisite that breathing and blowing should go on together. This may be difficult at first, but the necessary skill or tact is soon acquired. Let the learner attempt first to breathe through his nostrils with his cheeks inflated and mouth closed. This accomplished, if the blow-pipe is now put to the mouth, he will find no difficulty in continuing his respirations while the muscles of the inflated cheeks are throwing their contained air through the blow-pipe. When the air is nearly exhausted, the mouth may again be filled through the nose without intermitting the process of blowing.

The blow-pipe flame consists of two cones—an inner of a blue color, and an outer, yellow. The heat is most intense just beyond the extremity of the blue flame. The inner flame is called the *reduction* flame, and the outer the *oxydation* flame. A mineral reduced to the metallic state by the *inner*, may often be oxydized, or combined with oxygen, in the *outer* flame, where it is in contact with the atmosphere. For oxydation, the beak of the blow-pipe should have a large aperture, and the wick of the lamp should also be large: the heat may be that of incipient redness.

When it is desired to produce a reducing action, the point of the blow-pipe is just allowed to touch the flame, which should completely envelop the assay. See Fig. 92.



Fig. 92.

To produce an oxydizing action, the point of the blow-pipe should be inserted a little into the flame, and the assay should be placed at or a little beyond the point of the flame. See Fig. 93.

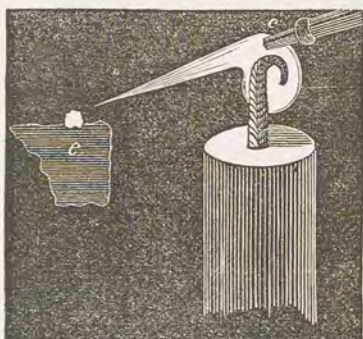


Fig. 93.

The best flame is that of a lamp with a large wick, fed by olive oil. A common candle with a large wick will answer for most of the purposes of the mineralogist, and is most conveniently carried about. When used, the wick should be bent in the direction of the flame.

To support the mineral in the flame, either charcoal or platinum forceps or wire may be used. The charcoal should be well burnt but firm; that from pine wood is the best, as it burns with least ashes. The reaction of the carbon of the coal aids in reducing or decomposing many mineral species.

A convenient kind of forceps is represented in the annexed figure. It is made of steel, with platinum points



Fig. 94.

and pins for opening the forceps. The mineral kyanite, and also mica, are sometimes used for a support when more convenient means are not at hand.

To test the presence of water or a volatile ingredient, the mineral may be supported near one end of a test-tube, which may be three or four inches long, and the bore little larger than a quill. The end is then heated with a spirit-lamp, or the flame is concentrated on the exterior of the tube beneath the assay, and the volatilized substance usually condenses in the upper part of the tube. By inserting into the upper end of the tube a strip of litmus or other test-paper, it is ascertained whether the fumes are acid or not, the color of the paper, if so, changing to red. See Fig. 95.



Fig. 95.

The specimen to be subjected to the flame of the blow-pipe should be a very small, *thin* fragment, especially when the mineral is not very fusible; for fusion is often thus obtained, when impossible with a fragment without thin edges. A fragment as large as a pea might afford a score of pieces, large

enough for a blow-pipe trial.

Many minerals remain unaltered before the blow-pipe, unless some substance be added to aid in the fusion or reduction. These substances are called *fluxes*. Those in common use are *borax*, *carbonate of soda*, and *salt of phosphorus* or *microcosmic salt*.* Care should be taken to obtain the fluxes pure, and for this purpose it is well to dissolve and re-crystallize the borax; and the soda should be tested for sulphuric acid, as any adulteration with this acid will give the glass obtained with silica a brown or reddish color. These fluxes should be powdered and added to the mineral, and the whole assay

* This salt, a phosphate of soda and ammonia, may be made by dissolving sixteen parts of sal-ammoniac in a small quantity of boiling water, and afterward adding one hundred parts of crystallized phosphate of soda, boiling gently the whole, and then setting it away to cool. The *salt of phosphorus* is deposited in small crystals. If the heat be too great during ebullition, decomposition takes place.

should not exceed the size of a small pea. One fourth this size is better than larger. The soda should be added in small successive doses; this flux is often absorbed by the charcoal, but generally reappears when the heat is sufficiently raised.

Besides the fluxes mentioned, other tests are sometimes used, of which the following are the most important:

a. Nitrate of cobalt in solution, for distinguishing alumina and magnesia. This solution should be pure, free from alkali and slightly concentrated. Berzelius recommends having a bit of platinum wire in the cork stopper, in order to take out a drop upon it when required for use.

b. Boracic acid and *iron wire*, used in testing for phosphoric acid.

c. Tin-foil, for using with certain peroxyds of metals to reduce them to protoxyds. The assay, previously heated in the reducing-flame, should be touched with the end of the tin foil: a very minute quantity of a metallic oxyd is often thus detected.

d. Gypsum and *fluor*, used as tests of one another. When two parts of the former, rendered anhydrous by heating, and one of the latter, are mingled and heated, they fuse to a clear glass, which is a milk-white enamel on cooling. The globule from fluor and heavy spar is transparent when cold; and that with sulphate of strontian is more or less frothy.

e. Saltpetre is employed in discovering manganese, bringing out the characteristic amethystine color when the quantity of this metal is too small to color glass without this reagent. The heated globule is touched with the point of a crystal, just at the moment of suspending the blast. The melted mass swells, foams, and either becomes immediately colored, or is so soon, upon cooling.

f. Anhydrous bisulphate of potash, used for detecting lithia. It is kept in a coarse powder in a vial well secured from moisture.

g. Oxalate of nickel, or *nitrate of nickel*, used to de-

tect potash. The nickel must be quite free from cobalt; it may be tested by treating it with borax, with which it should give a brown, not a blue bead.

h. Nitroprussid of sodium,* for detecting sulphur.

The effects of the blow-pipe are various. Some minerals are volatilized wholly or in part, others fuse at a low temperature; while others melt only on the edges, (then called *subfusible*,) or are wholly infusible. Kobell has proposed the following scale for denoting in figures the degree of fusibility: 1. *Gray antimony*. 2. *Natro-lite*. 3. *Cinnamon Stone*, (var. of garnet.) 4. *Black Hornblende*. 5. *Feldspar*. 6. *Chondrodite*. The fusibility, when equal to that of natroline, is designated by 2; or if like hornblende, by 4, and so on.

The fluxes are also often required in obtaining the pure metals from the metallic ores.

The following are some of the reactions with the fluxes:

1. *Silica, Silicates*.—Silica dissolves with effervescence in soda. The silicates are decomposed by salt of phosphorus, and the silica is set free, often remaining as a silica skeleton in the globule. *Columbic acid*, on the contrary, forms a clear glass with salt of phosphorus.

2. *Potassa, Soda, Lithia*.—Soda gives an intensely yellow color to the flame, even when in combination; yet this color may be otherwise produced. Potash salts often give a violet tinge, and a lithia salt a red color to the flame; but the presence of soda vitiates the test by communicating its own color. A glass of borax containing potash becomes blue when a little oxalate of nickel is carefully added, and one of soda, brown; and this

* It is readily obtained by treating two parts of the powdered ferrocyanid of sodium with five parts of common nitric acid previously diluted with its own volume of water. The solution, when the escape of gas has ceased, is heated in a water bath, until a salt of the protoxyd of iron gives a slate-colored (and no longer a blue) precipitate. It is then cooled, when a precipitate forms; the liquid is next filtered and neutralized with carbonate of soda, when a green or brown precipitate goes down, leaving it ruby colored; this liquid is poured off and evaporated, a crystallization takes place of nitrate of potash and soda, together with the new salt, the last in crystals of a splendid ruby-red color.

holds good for the potash salt, although soda be present. A lithia salt fused on platinum foil, if soda be present, produces a yellow stain; but this stain is produced also by other reagents. If a lithia mineral be mixed with one part of fluor finely pulverized, and one and a half parts of bisulphate of potash, the flame is red; if no lithia is present, it is faint violet.

3. *Lime*.—Lime and lime salts give a brilliant white light. They sometimes tinge the flame reddish, but more faint than carbonate of strontia.

4. *Magnesia*.—Magnesia and many magnesian silicates afford a clear rose-red color with cobalt solution, after a long heat. A fragment after heating should be moistened with the solution and then heated again; the color deepens on cooling. Magnesia is not acted on by soda.

5. *Alumina*.—If a fragment of alumina, or if an aluminous silicate, after heating to redness, be moistened by cobalt solution and again heated, but not to fusion, it assumes a fine blue color. The harder species should be finely pulverized. The test is sure except when oxyds of certain metals are present; and also when saltpetre is present, since it gives a blue color with silica and zirconia, and in some other cases.

6. *Arsenic and Arsenical Compounds* give off usually arsenical fumes having an alliaceous odor when heated on charcoal or with soda. With many of the compounds heated in a tube, white arsenic or orpiment is condensed; and with charcoal metallic arsenic is obtained on the tube in crystals. Fig. 96 shows the form of tubes employed for this purpose.



Fig. 96.

7. *Selenium and Seleniurets* give a horse-radish odor

in the outer flame on charcoal ; yield in a tube a sublimate in the form of a dark red powder.

8. *Sulphurets*.—A glass made of soda and silica becomes red or orange yellow when sulphur is present. Heated on charcoal with soda and then adding a drop of water, the sulphurets yield sulphuretted hydrogen, which blackens silver-foil or test-paper containing acetate of lead. Heated in a glass tube closed below, with litmus paper above, they redden the paper and yield often a sulphurous odor.

A more delicate test for sulphur is the *nitroprussid of sodium*, as published by Professor J. W. Bailey. Heat by blow-pipe any sulphuret or sulphate (or any thing containing sulphur) upon charcoal with carbonate of soda, put the fused mass into a watch-glass, with a drop of water, and add a particle not larger than a pin's head of nitroprussid of soda ; there will be a magnificent purple at once. If this test for sulphur is tried upon parings of nails, hair, albumen, etc., the carbonate of soda should be mixed with a little starch, which appears to prevent the loss of any of the sulphur by oxydation. On winding up a piece of hair four inches long, by coiling it around one point of a platinum support, moistening it and dipping it into the mixture of carbonate of soda with starch, and then heating by the blow-pipe, the fused mass will give with the nitroprussid an unmistakable action indicative of sulphur. By careful management, perfectly satisfactory results may be obtained from a piece of hair less than an inch long.

9. *Tellurium and Tellurids* give fumes but no odor. Heated on charcoal, the oxyd covers the charcoal with a brownish yellow coating, and the inner flame directed upon this coating is tinged bright green. In a tube the fumes rise and coat the glass, and when heated the coating melts into drops, which are but slowly driven off by the continued heat.

10. *Chromium*.—Oxyd of chromium with borax gives an emerald green color ; but on platinum wire in the outer flame the color nearly disappears. Chromic iron

gives the same color, and it is brightened on the addition of tin-foil.

11. *Antimony*.—The orès of antimony afford fumes usually white on charcoal, which are inodorous. The oxyds form with soda on the platinum wire, a clear, colorless bead, which becomes white on cooling; on charcoal they are reduced. In an open tube, antimony gives white fumes, which coat the glass and vaporize easily on a new application of the heat, without fusion to globules.

12. *Bismuth* fuses and gives off inodorous fumes. On charcoal it becomes surrounded with a dark brown oxyd, which is pale yellow on cooling; the flame directed on the coating is not tinged; ultimately the metal is wholly vaporized.

13. *Titanium*.—Titanic acid with borax yields a colorless glass, which becomes milk-white on flaming, if not without. In the inner flame, the glass with little of the assay is first yellow and afterward amethystine and transparent. With more assay on charcoal in the inner flame, becomes dark blue or nearly black on cooling; but it is pale blue afterward on flaming. With salt of phosphorus, it forms in the outer flame a clear, colorless glass; in the inner flame, a red or violet-blue glass, when cold, especially if tin be added. When iron is present, the color after heating in the inner flame is deep red on cooling. Siliceous titanic minerals, as sphene, do not give the reaction with borax, except after long heating in the inner flame with salt of phosphorus, and it is apparent only on cooling.

14. *Tin*.—Oxyd of tin is slowly dissolved by borax to a transparent glass, which is transparent on cooling. With soda or cyanid of potassium on charcoal it is easily reduced; and if borax also be added, a very minute quantity of tin may be detected when present in other minerals.

15. *Cerium*.—Oxyd of cerium affords with borax and salt of phosphorus a fine red or dark yellow glass in the outer flame, which becomes white on flaming. The protoxyd changes to peroxyd, and the latter is not changed

in the inner flame. In the compounds with silica, cerium is not distinguishable from iron by the blow-pipe.

16. *Lead*.—Minium is black while hot, but at a low red heat changes to a yellow oxyd. The ores of lead on charcoal, with or without soda, are reduced; unlike tin, they often give a coating of oxyd on the charcoal when heated in the outer flame.

17. *Zinc*.—Oxyd of zinc with borax gives a clear glass, which is milk-white on flaming; or with more assay is enamel-white on cooling. In the inner flame on charcoal, fumes are given off and a white coating surrounds the assay. With soda on charcoal, the ores, even when containing little zinc, afford the peculiar bluish flame of burning zinc, and the oxyd is deposited on the coal. With cobalt solution, a green color, while tin give a bluish green.

18. *Cadmium*.—Oxyd of cadmium, even when in small proportions in other minerals, when heated on charcoal deposits a reddish brown powder; it forms from cadmiferous blende before the zinc begins to incrust the charcoal.

19. *Copper*.—Oxyd of copper gives a fine green glass with borax, which becomes cinnabar-red on cooling. The ores are reduced on charcoal with soda, and a malleable copper-colored globule obtained; when the copper is combined with oxyds that are reduced together with it, borax and tin should be used. If iron be present, the copper and iron are obtained separately.

20. *Manganese*.—Oxyd of manganese gives with borax in the outer flame an amethystine globule, (very deep, with much manganese,) which becomes colorless in the inner flame. With soda on platinum the oxyd gives a green color which is bluish green on cooling. When other metals are present, soda should be added, and then the bluish green color is obtained, even with less than one per cent of manganese.

21. *Iron*.—With borax in the outer flame, oxyd of iron gives a dark red glass, which becomes yellowish or colorless on cooling. In the inner flame it affords a bottle-green color, or a bluish green in a more perfect reduc-

tion. With tin the green color is hastened. The per-oxyl becomes magnetic when heated in the inner flame.

22. *Cobalt*.—Oxyl of cobalt gives a clear blue bead with borax, which does not become opaque on flaming. As in other metallic species, the sulphurets should be roasted before testing for the cobalt.

23. *Nickel*.—Oxyl of nickel forms a dark yellow or reddish glass with borax, which is nearly colorless on cooling; but with more of the oxyl, the glass is dark brown, while hot, and becomes red on cooling; and with saltpetre in the outer flame, the color is changed to a blue or deep purple, distinguishing it from oxyl of iron.

24. *Silver*.—The ores on charcoal, with, if not without, a flux, are reduced to the metallic state. But when other metals are present, lead is to be mixed with the assay, with the borax, and thus an alloy of lead and silver formed, from which the silver may be obtained by cupellation.

25. *Chlorids*.—A dull green pearl, made by dissolving a little oxyl of copper in salt of phosphorus, becomes surrounded by a fine blue or purple flame if a chlorid be added, which continues till the chlorine is expelled.

26. *Fluorids*.—When fluorids are heated with salt of phosphorus previously melted in an open glass tube, the glass is corroded, and Brazil paper, placed within the tube, is turned yellow. The salt of phosphorus for this experiment should be free from all chlorids. If the fluorine is present only in small quantity, the assay may be heated in the same way without the salt of phosphorus.

27. *Sulphates*.—Like the sulphurets, in their reaction with a glass of borax and silica.

28. *Nitrates*.—deflagrate on burning coals, and also give off a red gas when heated in a matrass with a drop of sulphuric acid.

29. *Phosphates*.—If a phosphate be fused with boracic acid, and the extremity of a small iron wire be inserted into the melted globule and the whole be heated in the reduction-flame, the globule formed at the extremity of the wire will prove to be more or less brittle when struck with a hammer on an anvil. As the bead cools,

a flash of light is usually seen. Before this trial it should be ascertained that no sulphuric or arsenic acid is present, which may also form a globule with the iron; nor any metallic oxyd reducible by the iron.

30. *Borates*.—When a borate is melted with three parts of the flux called Turner's reagent, (a mixture of two parts of fluor spar and one of bisulphate of potash,) the flame at the instant of fusion is brightly tinged with green. This trial should be made in a dark place.

For a more complete account of the blow-pipe and of its use in chemical analysis, reference may be made to the treatise by Berzelius (Whitney's translation) and also that of Plattner.

In addition to the instruments already described, the following are important: 1. *A small hammer*, with a slightly rounded face and a transverse sharp edge at the other extremity. 2. *An anvil*, or piece of steel three inches long, one broad, and three sixteenths thick—to be used for pulverizing minerals, for which purpose the specimen should be first wrapped in a piece of paper. 3. *Platinum foil*, for enveloping minerals that decrepitate. 4. *Fine platinum wire*, bent at one end into a circle one or two lines in diameter; it very conveniently holds the assay in fusion. 5. *Cutting pliers*, for separating small fragments of a mineral for assay.

Fig. 97 represents a little drill for boring holes in the charcoal, that the assay may not be blown away by the blast. It has the form of a cross, or of two chisels crossing at right angles. It is often convenient to place the assay with the flux in a little tube of paper, so as to prevent any loss before it is thoroughly melted. A little wooden cylinder, *a*, Fig. 98, is a convenient piece of apparatus for forming these. It should be rather smaller in diameter than the drill, Fig. 97. Fine letter-paper, cut into strips one and a half inches by one, is rolled round the cylinder, being allowed to project beyond it to a distance equal to the diameter of the cylinder. The projecting end is then turned down, beginning at the end of the strip, and a closed tube is thus formed in which the assay may be placed.

Fig. 99 represents a brass capsule two and a half inches long and a quarter of an inch in its greatest depth, which is of a convenient form for mixing ores with fluxes.



Fig. 97.



Fig. 98.



Fig. 99.

Cupellation.—Cupellation is a process by which one metal in an alloy is oxydized and absorbed by a porous material, and the other left pure. It is used for separating silver and gold from lead. It is performed before the blow-pipe by making a small, rounded cavity in charcoal, about as deep as broad, (say one fourth of an inch,) putting in fine bone-ashes a little moistened, and made smooth by pressure, and upon this, after drying slowly, the assay; then heating in the outer flame. When the alloy of silver and lead is thus treated, the lead becomes an oxyd and is absorbed by the bone-ashes, and the silver, though extremely minute in quantity, remains as a brilliant globule in the cavity.*

The ordinary process of cupellation is as follows: The assay is heated in a small cup (called a cupel) made of bone-ashes, (or in a cavity containing bone-ashes,) *while the atmosphere has free access*. The heated metal is oxydized by the air passing over it, and the oxyd formed

* A table by Professor W. W. Mather is contained in the *American Journal of Science*, [2.] 3, 414, which gives the ascertained weight of globules of silver, of given diameters. Similar tables are given in different treatises on chemical analysis.

sinks into the porous cup, leaving the precious metal behind. The form of the cupel, *b*, the appearance of the assay, *c*, the proper position of the blow-pipe, and the form of the flame are represented in Fig. 100, which also shows a very good form of cupel-holder, *a*, for blow-pipe operations.



Fig. 100.

SYSTEMATIC PROCEEDING FOR DETERMINATION OF GOLD
AND SILVER ORES.

Sec. 10. The use of the following systematic proceeding can be understood easily by an example:

A silver mineral, for instance, approved as such by examination on silver, must be observed first as to what lustre it shows, or whether it is dull. Suppose, then, the mineral has a metallic lustre. (See I.) The color must be observed next, and compared with those under I. The ore is further found to be "lead gray." We have then to proceed from the indicated letter, B, on the right side, to B on the left, and examine accordingly, whether the mineral gives a sublimate or not. If, for instance, no sublimate has been obtained, we must proceed to *c*,

as indicated. On the described examination under *c*, the mineral appears tough; it can be cut with a knife. We go over to Section 16, and see the numbers 2 and 20, Silverglance and Hessite. The description of both will lead to the right determination of the mineral.

I.—*Lustre metallic or Sub-metallic.*

Color, white, grayish-white, yellowish-white, or yellow, see	<i>A</i>
Color, lead-gray, blackish lead-gray, or iron-black,...	<i>B</i>
Color, light steel-gray,.....	<i>C</i>
Color, reddish lead-gray,.....	<i>D</i>
Color, pinchbeck-brown,.....	<i>E</i>

II.—*Lustre Resinous and Adamantine.*

Color, pearl-gray, yellowish green, green, olive-green, lemon-yellow, or light yellow, see.....	<i>F</i>
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III.—*Dull.*

Color, red, dark red, (sometimes externally lead-gray,)	<i>G</i>
Color, blackish blue,.....	<i>H</i>
Color, greenish black,.....	<i>I</i>
<i>A</i> It can be cut with a knife, see.....	<i>a</i>
<i>A</i> Can not be cut; is brittle,.....	<i>b</i>
<i>B</i> In a closed tube, no sublimate, even under the blow-pipe,.....	<i>c</i>
<i>B</i> It gives a sublimate, with or without the blow-pipe,	<i>d</i>
<i>C</i> In a closed tube, no sublimate,.....	<i>e</i>
<i>C</i> It gives a sublimate,.....	<i>f</i>
<i>D</i> In a closed tube, dark-red, sublimate. See Sec. 16, (8 or 9.)	
<i>E</i> In a closed or open tube, no sublimate. See Sec. 16, (4.)	
<i>F</i> In a closed or open tube, no sublimate,.....	<i>g</i>
<i>F</i> Gives, with the aid of the blowpipe, a slight sublimate,.....	<i>h</i>
<i>G</i> In a closed tube, red brown or reddish-yellow sublimate. Sec. 16, (10.)	

- G* It gives three sublimes—black, yellow, and gray. Sec. 16, (16.)
- H* In an open or closed tube, no sublimate. Sec. 16, (3 *a'*.)
- I* In an open or closed tube, no sublimate. Sec. 16, (11 *a'*.)
- a* It melts on charcoal to a metallic white globule. Sec. 16, (1.)
- a* It melts on charcoal to a metallic yellow or yellowish globule. Sec. 15, (1.)
- b* It melts on charcoal to a globule of metallic lustre, coating the coal white. Sec. 16, (17.)
- b* It decrepitates somewhat, giving, before fusing, a slight, very volatile whitish coating. Sec. 15, (4,) or Sec. 16, (22 or 23.)
- c* It can be cut with a knife. Sec. 16, (2 or 20.)
- c* It can not be cut; is brittle. Sec. 16, (3 or 4, *a* or 6,) or Sec. 15, (2.)
- d* In a closed tube, it gives a reddish-yellow sublimate. Sec. 16, (6 *a'*.)
- e* On charcoal it fuses, giving a yellow and white coating. Sec. 15, (3.)
- f* In a closed tube, by aid of the blowpipe, a dark red sublimate. Sec. 16, (11.)
- g* On charcoal it fuses, emits an acrid odor, and leaves globules of silver; in a closed tube, with bisulphate of potassa, emits no colored vapors. Sec. 16, (12.)
- g* It gives, with bisulphate of potassa, red-brown vapors. Sec. 16, (13 or 14.)
- h* In a closed tube, with bisulphate of potassa, violet vapors. Sec. 16, (15.)

DESCRIPTION OF GOLD AND SILVER ORES.

A.—GOLD ORES.

SEC. 15. Gold appears mostly in metallic condition, but never free from silver. It is found generally in the form of grains, scales, dust, also in the shape of leaves, threads, or crystals. It is not ascertained but supposed,

that a part of the gold in iron pyrites does not exist in metallic state, but combined with sulphur, or with arsenic in the arsenical pyrites. The gold is found in combination with the following metals:

1. *Silver*.—In different proportions. The gold of Gold Hill lode, N. T., contains forty-seven to fifty per cent of silver; that of the Comstock lode, thirty to forty-five; Gila River and Australian gold, three to five per cent. According to the amount of silver, the gold appears more or less whitish. Sixty per cent of silver renders the alloy white.

On charcoal, treated with the oxydation flame, it gives sometimes a bluish-white coating of antimony. With borax, played upon with reduction flame, a reaction of copper may be observed.

2. *With Tellurium*.—It contains gold, 26; silver, 14; tellurium, 59; with traces of lead, copper, and antimony, hardness, 1.5; gravity, 5.7 to 5.8; lustre, metallic; color, light gray.

In an open tube it emits white fumes, and gives a gray sublimate of tellurium. Directing the flame on the sublimate, it melts into transparent drops. The fumes have a peculiar sour odor. On charcoal, it melts to a dark-gray globule. Played upon with the oxydation flame, it gives a white coating, which disappears with a bluish-green color, under the oxydation flame. Continued blowing yields a yellow, bright gold button.

3. *With Tellurium and Lead*.—Gold, 9; tellurium, 32; lead, 54, with traces of copper, sulphur, and antimony; H.=1.5; Gr.=7-7.72; color, dark lead-gray.

In an open tube it fumes, and yields a gray sublimate, the upper part of which, formed by antimonious acid, can be driven away by the flame. On charcoal it fumes and gives two coatings—a white one, which is volatile, consisting of tellurous and antimonious acids and sulphate of lead; the other coating is yellow, less volatile, and consists principally of oxyd of lead. Continued blowing leaves a small metallic button, showing gold color when cupeled.

4. *With Mercury and Silver*.—Gold, 36; silver, 5;

mercury, 58. The gold is found also alloyed with molybdenum, platinum, and rhodium.

B.—SILVER ORES.

SEC. 16. Silver is found mostly in combination with sulphur, also alloyed with other metals and substances. It appears often in metallic condition.

1. *Native Silver*—Is found crystallized, in threads or filaments. It often contains a small amount of antimony, arsenic, iron, gold, or copper. The native silver, one variety of the Comstock lode, N. T., contains, silver, 60–85; gold, 1.9; lead, 8–30; copper, 1–5; H.=2.7–3; Gr.=10.6–11.3. Heated on charcoal, it becomes covered with lead globules, disappearing again when red hot. It gives a yellow coating of lead, and further off, a bluish-white of antimonious acid. It colors the borax glass green with the oxyd of copper.

a. Combination with Sulphur.

2. *Silver Glance, (Sulphuret of Silver.)*—Silver, 87; sulphur, 12.9; H.=2.5; Gr.=6.9–7.2; lustre, metallic; color and streak, blackish lead-gray; streak, shining. It may be cut like lead. On charcoal, it melts into a dark blue globule, generally emitting metallic silver on the surface on cooling, especially if a small particle of borax glass is added, which dissolves impurities. It yields a silver globule when melted with soda.

3. *Stromeyerite, (Silver-Copper Glance.)*—Silver, 50–53; copper, 31; sulphur, 15; H.=2.5; Gr.=6.2; lustre, metallic; color, blackish lead-gray. In a closed tube, gives sometimes a little sulphur sublimate; in an open tube, sulphurous acid. On charcoal, it fuses to a steel-blue globule, emitting sometimes metallic silver on cooling. Melted with soda, it gives a copper button, which yields silver when refined. It occurs in the Heintzelman mine, Arizona.

a'. A variety of this ore, containing 40–33 per cent of silver, with a dull blackish-blue color; streak, shining; can be cut; occurs in Arizona.

4. *Sternbergite*, (*Sulphuret of Silver and Iron*).—Silver, 30–33; iron, 36; sulphur, 30; $H.=1$; $Gr.=4.2$; metallic lustre; color, pinchbeck-brown; streak, black. In thin laminae, flexible, resembling graphite. In an open tube it gives out sulphurous acid. It melts to a globule on charcoal, emitting silver, and follows the magnet.

a'. A variety of this ore is found in the Gold Hill lode, N. T. It consists of silver, 33.25; iron, 34.05; $H.=2.8$; $Gr.=5.2$; color, dull bluish-gray. The fracture has a metallic lustre and dark lead-gray color. The powder is blackish-brown. It is found in small fragments of indistinct cubic shape. On charcoal, it melts, with a spongy appearance, to a dull gray globule, following the magnet. A slight yellow coating indicates a trace of lead. In melting, it gives out a great deal of sulphurous acid. Treated with soda, a silver globule is easily obtained.

b. Combinations with Sulphur and Antimony, or Arsenic.

5. *Brittle Silver Ore*.—Silver, 70; antimony, 13.9; sulphur, 15.7; $H.=2.5$; $Gr.=6.2$; lustre, metallic; color and streak, iron-black, or blackish lead-gray. In a close tube, it decrepitates, melts to a globule, and gives a blackish sublimate, which turns red-brown when cold, consisting of sulphide of antimony. In an open tube it melts, evolving sulphurous acid, and fumes. On charcoal it fuses, and coats the coal white with antimonious acid. By continual blast, the coating assumes a pink color, derived from the oxyd of silver. It occurs frequently in the Comstock lode.

6. *Polybasite*, (*Eugen Glance*).—Silver, 64–72; copper, 3–10; sulphur, 17; $H.=2.5$; $Gr.=6.2$. It contains also antimony, arsenic, iron, and sometimes zinc. Lustre, metallic; color, iron-black; streak, black. In a closed tube it yields nothing volatile. In an open tube it gives antimonial fumes and sulphurous acid. It occurs also in Gold Hill lode, N. T.

a'. The polybasite of the Comstock lode contains 64

per cent of silver. It gives, in a closed tube, with the aid of the blow-pipe, a reddish-brown sublimate, with a yellow edge. In an open tube, white fumes arise, and some white sublimate deposits. On charcoal, with the reduction flame, it evolves an odor of garlic. Played upon with the oxydation flame, it gives out sulphurous acid and a white coating of antimonious acid. It melts to a globule with a metallic lustre. If the hot blast is changed suddenly to a cold one, and directed on the globule, holding the blow-pipe point close to it, metallic silver is emitted. If the cold blast is stopped too soon, the silver will disappear again.

7. *Miargyrite*.—Silver, 35.8; antimony, 42.8; sulphur, 21; H.=2.5; Gr.=5.2–5.4; lustre, metallic adamantine; color, iron-black; streak, dark cherry-red. In a closed tube it decrepitates, melts easily, and gives out a sublimate of sulphide of antimony. In an open tube, sulphurous acid and antimonial fumes are emitted, depositing a white sublimate of antimonious acid. On charcoal it melts quietly, emitting sulphurous acid and antimonial fumes. It covers the coal with a white coating, which becomes pink-colored by continual blast. Melted with soda, a silver button is obtained, which, treated with borax and tin, reacts on copper.

8. *Dark red Silver Ore, (Pyrargyrite, Antimonial Blend)*.—Silver, 58.9; antimony, 23.4; sulphur, 17.5; H.=2.5; Gr.=5.7. Lustre, metallic-like adamantine; color, dark red; powder, cochineal-red. In a closed tube by the aid of the blow-pipe, it yields a sublimate or sulphide of antimony, black while hot, but varying from red to reddish-yellow, when cold. In an open tube, it gives antimonial fumes and sulphurous acid. On charcoal it melts easily, and deposits a white coating of antimonious acid. With soda, it gives a silver globule. It occurs also in the Gold Hill lode, N. T.

9. *Light red Silver Ore, (Proustite, Arsenical Blend)*.—Silver, 65.4; arsenic, 15.1; sulphur, 19.4; H.=2.5; Gr.=5.5–5.6; color, similar to dark red silver ore, but lighter. Behaves like the preceding, except the arsenical fumes.

10. *Xanthocone*.—Silver, 64; arsenic, 13.4; sulphur, 21.3; H.=2; Gr.=5-5.2; color, dull red to clove brown; powder, yellow. When heated in a closed tube it becomes dark red, melts, and gives some sublimate of sulphide of arsenic. While hot, it is dark, brownish-red, and red to reddish-yellow when cold. In an open tube and on charcoal, it behaves like the preceding.

11. *Silver Fahlerz*, (*Argentiferous Gray Copper Ore*.)—Silver, 17.71-31.29; antimony, 26.63-24.63; sulphur, 23.52-21.17; copper, 25.23-14.81; iron, 3.72-5.98; zinc, 3.10-0.99; lustre, metallic; color, light steel-gray. In a closed tube it sometimes decrepitates, melts, and gives, by aid of the blow-pipe, a dark red sublimate of tersulphide of antimony, with antimonious acid. In an open tube it fuses, gives antimonial fumes and sulphurous acid. On charcoal it fuses easily, and gives a bluish-white coating of antimonious acid and antimonial fumes. There is also a yellowish coating close to the test, which appears white on cooling. This coating is created by oxyd of zinc.

a'. The Reese River ore, from the Comet lode, seems to be a metamorphosed silver fahlerz. The sulphur is represented by carbonic acid, so that almost all copper and silver is a carbonate. It contains silver, 22.35, copper, 17, antimony, and some lead. It has a dull greenish-black or black color; streak, shining; powder, greenish-gray. In a closed tube it yields nothing volatile. In an open tube some sulphurous acid can be observed. On charcoal, fuses slowly, but boils up suddenly in contact with glowing coal, leaving a button of silver and copper. This button, when played upon with the oxydation flame on another spot of the charcoal, gives first a bluish coating of antimonious acid, then a yellow one, nearer to the assay of the oxyd of lead. The silver can be separated from copper by cupellation with lead.

b'. The silver fahlerz of Sheba lode (Humboldt) contains, silver, 8.20, gold, 0.008, some antimony and lead, but very little copper. It has a light gray metallic lustre. It is also called gray silver ore.

c. Combination with Chlorine, Bromine, and Iodine.

12. *Horn Silver, (Chloride of Silver).*—Silver, 75.2; chlorine, 24.6; H.=1.5; Gr.=5.5–5.6; lustre, adamantine; color, gray, greenish or blackish; streak, shining. It looks like horn or wax. It is translucent, and may be cut like wax. Occurs frequently in the Comstock and Gold Hill lodes, also in California. It fuses in a candle flame. On charcoal it is easily reduced, and gives an odor of chlorine. If treated under the reduction flame, with an addition of copper, it forms a chloride of copper, and colors the flame azure-blue.

13. *Embolite, (Chlorobromide of Silver).*—Silver, 66.9 to 75; H.=1–1.5; Gr.=5.3–5.4; lustre, resinous; color, yellowish-green or green. On charcoal it fuses easily, evolves vapors of bromine, and gives metallic silver. Mixed with oxyd of copper, it colors the flame greenish-blue.

14. *Bromyrite, (Bromie Silver).*—Silver, 57.56; bromine, 42.44; H.=1–1.5; Gr.=5.8–5.6. In a closed tube, treated with bisulphate of potassa, it emits brown vapors. On charcoal it fuses easily and yields a globule of silver. It is yellow or greenish, and may be cut like chloride of silver.

15. *Iodyrite, (Iodide of Silver).*—Silver, 46; iodine, 54; H.=1.5; Gr.=5.5; lustre, adamantine; color, yellow, also greenish. It is translucent. In scale shape it is always lemon-yellow. When heated in a closed tube it becomes fire-red, but assumes its former color when cold. It fuses easily, and gives, by the aid of the blow-pipe, a reddish-yellow sublimate, getting lemon-yellow on cooling. With bisulphate of potassa, it emits beautiful violet vapors. In an open tube it gives an orange sublimate, lemon-yellow on cooling. On charcoal it assumes a fire-red color before it fuses, and spreads on the coal and yields many minute silver globules. With an addition of oxyd of copper, it makes an intensely green flame with a bluish tinge.

16. *Iodide of Silver and Mercury.*—Silver, 40–42; iodine, quicksilver, and sulphur, (chlorine?) color, dull,

dark red; streak, shining; powder, dark red, but changes soon into lead-gray, if exposed to the light. In a closed tube it gives three sublimates, separated in rings. The nearest to the assay is black, (sulphide of mercury,) the second, yellow, (subchloride of mercury?) the third is gray, (metallic mercury.) An addition of bisulphate of potassa causes it to yield violet vapors, which come from the iodine. In an open tube it gives the same sublimate, but the black is very slight; it gives also yellow fumes. A gold particle in the tube becomes amalgamated. Litmus paper at the upper end is colored red by the sulphur. Heated on charcoal it turns black, fuses easily, and yields silver globules. Melted with soda, it draws partly into the coal. If this crust is broken out and laid on a blank piece of silver, with a drop of water, the sulphur in it will cause a black spot on the silver. Heated with a small piece of pure lead, it gives a beautiful green coating, with a yellow border, nearest the assay. This coating (iodine and lead) is far off from the test. With copper oxyd, like the iodyrite.

This mineral occurs, to my knowledge, only in the Heintzelman mine, Arizona.

d. Combination with Antimony.

17. *Antimonial Silver*.—Silver, 77-84; antimony, 23-16; H.=3.5; Gr.=9.4-9.8; lustre, metallic; color and streak, silver-white. On charcoal it fuses easily to a globule, coating the coal white. A continual blast renders the white coating reddish.

e. Combination with Selenium.

18. *Naumannite, (Selenid of Silver)*.—Silver, 73; selenium, 26; H.=2.5; Gr.=8; lustre, metallic; color, iron-black. It melts easily on charcoal, but with intumescence in the reduction flame. It emits the selenium odor of rotten radish. With soda it yields metallic silver.

19. *Eucairite, (Selenid of Silver and Copper)*.—Silver, 43.1; selenium, 31.6; copper 25.3; lustre, metallic; color, lead-gray. On charcoal it melts to a gray metal-

lic globule, fumes, and reacts on borax with copper. This mineral is soft, and can be cut with a knife.

f. With Tellurium.

20. *Hessite, (Tellurid of Silver).*—Silver, 62.42; tellurium, 36.96; iron, 0.24; Gr.=8.4–8.6; lustre, metallic; color, lead-gray or steel-gray. It is soft, and can be cut like lead. According to Mr. Blake, this mineral is found in California also. He describes the reaction as follows:

“In an open tube the mineral fuses quietly, coloring the glass a bright yellow under assay. A white or gray sublimate is deposited at a short distance, immediately over it, which, on being heated, fuses into transparent drops resembling oil. On charcoal it fuses to a leaden-colored globule, which, on cooling, becomes covered with dendrites. This globule flattens under the hammer. With the addition of soda, a silver globule is obtained.”

f. With Bismuth.

21. *Bismuth Silver.*—Silver, 60; bismuth, 10; copper, 7.8, and some arsenic; lustre, metallic; color, tin-white or grayish. On charcoal it melts easily, covering the coal dark orange. It is yellow while hot, and lemon-yellow when cold. The oxyd of copper in it colors the borax green, when melted on charcoal.

g. With Mercury.

22. *Silver Amalgam.*—Silver, 34.8–26.2; quicksilver, 65.2–73.7; H.=3.5; Gr.=13.7–14; lustre, metallic; color, silver-white; brittle. In a closed tube the mercury sublimates.

23. *Arguerite.*—Silver, 86.49; quicksilver, 13.51. It behaves like the amalgam.

AN ABSTRACT
OF
MINING LAWS AND REGULATIONS
IN THE
PACIFIC STATES AND MEXICO,
COLORADO AND THE BRITISH POSSESSIONS.

I. GENERAL PRINCIPLES OF MINING LAW.

THE title to the lands upon which the mines in the great metallic regions of the Pacific Coast and of the Rocky Mountains are found, (including, of course, the mines themselves,) still rests, with some unimportant exceptions, in the United States.

The rights of the individual miners, as well as the rights of the incorporate bodies engaged upon these mines, rest, in the last analysis, purely upon the right by possession. This title is absolute and indefeasible, as between the miner in possession and all the world, except only the right of fee simple, of which the United States has never divested itself.

As to what constitutes possession and what surface of earth, or what length of a metallic vein may thus be held, is a matter regulated solely by the miners themselves, who meet in convention and frame a body of mining laws, such as will meet the wants of the particular locality or district in which their mines are situated.

In some cases, codes of a larger jurisdiction, covering the whole of a mining region, and embracing many dif-

ferent districts, have been framed by general conventions of miners meeting in some central district. This is the case particularly in Colorado.

These bodies of rules or miners' codes have been often recognized by the State and Territorial courts, as determining the extent and character of the possessory titles and of all the rights of which the subject is capable, short of a full grant from the United States, as the true and ultimate owner.

More than this: the United States have recognized, expressly as well as tacitly, these possessory rights and the humble but constitutional codes of miners by which such possession is regulated or proved.

Neither has the Government, as yet, taken any steps to assert its title, or expel those who, by discovery and by an occupation regulated by local law, have acquired titles which all but the Government are legally bound to respect. And yet the fact that the fee simple remains in the Government has been a great drawback to the mining community by increasing the difficulty with which European capital is induced to invest in these mining properties. But a familiar knowledge of the true condition of things in the mining regions, and a consideration of what has always been found to be the genius of American law, will convince any one that the probabilities are very small that the possessory titles, acquired under miners' laws, will ever be upset or even disturbed by any act of Congress.

Thus it is regarded in all the mining States and Territories.

The emigration to California immediately after the discovery of gold, carrying with it the principles of the common law, and, being thoroughly imbued with the spirit of equity and fair play, established in the various mining communities customs, rules, and regulations fixing the extent of mining claims, guarding against the possibility of monopoly, and defining what development and labor are required for retaining a valid and *bona fide* possession of mining property.

These rules and established customs, though formed

and adopted in a hundred different mining districts, without concert of action on the part of the miners, are remarkably similar in their general provisions, and were at an early date in California regarded so equitable and worthy of being incorporated into the established jurisprudence of the State, that the Legislature of 1851 passed the general law, as to miners' laws, as follows :

"That in actions respecting mining claims, the customs, rules, and regulations of the miners themselves may be offered in evidence, and when not in conflict with the Constitution of the State or of the United States shall govern the decision of the action."

Under this sanction of law, a system of mining regulations has grown up on the Pacific Coast, and has been commented on and sustained by courts of law, till it has become a body of jurisprudence as just, consistent, and as well defined as the common law of England or America on any important title.

Nor is this all. An act of Congress of twenty-seventh February, 1865, for providing a Federal Court in Nevada, has a clause declaring that "No possessory action between individuals in any of the courts of the United States, for the recovery of any mining title or for damages to any such title, shall be affected by the fact that the paramount title to the land on which mines are, is in the United States, but each case shall be adjudged by the law of possession."

As will more fully appear under the head which follows—"The established principles of California law as to mines and miners' rights"—the preëmption of the public lands has never been understood to extend to mineral but only to agricultural lands ; the rule as well as the policy of the State and general Government being to make the right of the farmer to use the land for his purposes, subordinate to the right of the miner to hunt for and extract the precious metals.

Congress has also adopted the same line of policy as to grants of land to States or corporations to aid in the construction of roads.

No. 10 of the Resolutions of the Thirty-eighth Congress, approved January 30th, 1865, provides :

"That no act passed at the first session of the Thirty-eighth Congress, granting lands to States or corporations to aid in the construction of roads or for other purposes, or to extend the time of grants heretofore made, shall be so construed as to embrace mineral lands, which in all cases shall be and are reserved exclusively to the United States, unless otherwise specially provided in the act or acts making the grant."

II. Principles established by the Highest Tribunals in California as to Mines and Miners' Rights.

1. *The State, rather than the United States, is the true proprietor of the mines.*

The State is entitled to all the rights in mines of gold and silver engaged by the crown under the common law. Such mines upon the public lands within this State belong not to the United States, but to the State of California. The United States, in its ownership of the public lands, occupies the same position as a private proprietor, except an express exemption from State taxation. The State has exclusive right to authorize the mines to be worked, pass laws for their regulation, to license miners, and affix other terms and conditions which she may think proper to the freedom of their use.

Hicks v. Bell, 3 Cal. R. 219.

Stokes v. Barret, 5 Cal. R. 36.

2. *Mining lands are devoted to mining purposes. The rights of the farming settler are subordinate to those of the miner.*

The statute of 1852 gives permission to all persons to work the mines upon public lands, although they may be in the possession of another for agricultural purposes. This right of the miner carries with it the right to the use of wood and water upon the public land when gold or silver has been discovered.

Acts of April, 1852, Sec. 1.

Tartar v. Spr. Cr. Min. Co., 5 Cal. 395.

As this doctrine is liable to abuse by persons entering upon lands under the pretense of mining, the Legislature of 1855 laid down the following principle:

3. *The miner shall give bond to remunerate the farmer upon the mineral lands of the State for any injury done his crops or buildings.*

Act of April 25, 1855.

4. *Persons settled in good faith on lots in mining towns, and carrying on business, are not to be disturbed in their possession by miners; nor has the miner a right to dig or put up mining works within the inclosure of a dwelling-house or corral.*

Fitzgerald v. Urton, 5 Cal. 308.

Tartar v. Sp. Cr. Co., 5 Cal. 395.

Burdge v. Underwood, 6 Cal. 45.

5. *Foreign miners must obtain license.*

The act of the Legislature prohibiting foreigners from working the mines except on condition of paying a certain sum monthly for the privilege, is not repugnant to the Constitution of the United States or the State Constitution, or to the treaties of the United States with foreign powers. Yet private parties can not execute this law, nor assume to disturb the quiet possession of others. A foreigner mining without license, if driven away by a private person, may recover possession in an action for the purpose.

Act of March 30, 1853, and of April 26, 1858.

Any person or persons hiring foreigners to work in the mines of this State shall be liable for the amount of the licenses for each person so employed.

Act of April 26, 1858.

See also 1 Cal. Rep. 232.

Mitchell v. Hagood, 6 Cal. R. 148.

6. *In actions about mining claims, the miners' laws of each camp, bar, or diggings, are admissible in evidence. Justices have jurisdiction in such cases up to two hundred dollars.*

Prac. Act of Cal. Sec. 621.

Lander v. Coe, 5 Cal. 230.

Van Elten v. Steele, 6 Cal. 19.

Small v. Gwinn, 6 Cal. 447.

7. *The justice may appoint a receiver, pending the action.*

Wood's Cal. Dig., Art. 1374.

8. *The right to use water, and questions about the diversion of a stream, are beyond the jurisdiction of a justice.*

Hill v. Newman, 5 Cal. R. 445.

9. *As among themselves, miners' rights are regulated by their own laws, and under decisions on the following points:*

(a) Actual possession of a part is a possession of the whole tract, according to the custom of the camp or mining district.

(b) The miner has such rights in his claim or patch that he can take away a dam that floods his grounds so he can not work.

(c) In the absence of mining regulations, the fact that one claim is bounded by another is no proof that the claim last located is similar in size and in the direction of its lines with the first.

7 Cal. R. 40.

(d) Where a person sells a claim on which he has made a verbal agreement to pay a workman in a part of the gold taken out, the buyer is not bound to respect this agreement.

8 Cal. R. 598.

(e) A miner may claim ground on which to put his tailings, but such claim may not impair former rights; and his intention thus to claim must be clearly apparent.

9 Cal. 237.

(f) In general, to suffer tailings to flow away without effort to stop them proves abandonment.

9 Cal. 237.

(g) To suffer tailings to flow over on another's claim is to give them to the owner of the claim, but it does not entitle a stranger to come in and wash them.

9 Cal. 237.

(h) Procuring machinery or working at a draw on other land is not such work on a claim as will enable one to hold where miners' laws require so many days' work a week on a claim to hold it.

Packer v. Heaton, 9 Cal. R. 568.

(i) A claim may be taken by two miners for different purposes, as for mining and for fluming, or for mining and to deposit tailings; but the first claimant has superior rights. *O'Keefe v. Cunningham*, 9 Cal. R. 589.

10. *The common law doctrines relating to water and running streams in mining localities have been greatly modified and accommodated to miners' interests in the following particulars:*

(a) A right to water exists without private ownership of the soil, on the mere ground of prior location on the land or prior use of the water.

(b) When a person has used water, and then suffered it to flow away from his land and pass into another's stream, he may not erect a dam on that stream for the purpose of taking out the water which he may have suffered to flow in.

Hill v. Newman, 5 Cal. R. 445.

(c) When a miner takes a claim on or near a creek whose waters have been diverted by some earlier enterprise, he has no ground of complaint, and can not make the earlier proprietors give up their dam and let the water flow in its old channel for his accommodation.

5 Cal. R. 140.

(d) Surveying the line for a canal, staking it out, and commencing work is such possession as will fix the right as against one who claims to have the water in its former bed.

6 Cal. R. 105.

6 Cal. R. 548.

(e) But cutting a ditch for a drain, or other purpose not connected with mining, will not defeat the rights of miners holding claims lower on its natural course, to have the water for mining enterprises.

7 Cal. R. 261.

(f) One who locates along the line of a ditch, and the water breaks out and overflows him can not recover damages of the canal owners unless the accident was the result of gross carelessness.

Tenney v. Miners' D. Co., 7 Cal. R. 335.

(g) He who first locates on a stream has a right to the water, and no subsequent location, so as to prevent

his using the water, can be sustained. Damages are recoverable for erecting such obstructions.

Sims v. Smith, 7 Cal. R. 148.

(h) The first appropriator of water has a right to have the water as first used by him, without material diminution by the erection of any dam or flume above him.

8 Cal. R. 327.

(i) When parties build a flume or canal for taking out a certain part of a stream, they may continue to take out so much, but can not enlarge their flume so as to take out more than it was their first intention to appropriate.

White v. Todds Valley Wat. Co., 8 Cal. Rep. 443.

11. *Mining claims and water rights can not be transferred by bill of sale merely. They are in the nature of real estate, and should pass by a sealed instrument.*

Hill v. Newman, 5 Cal. R. 445.

12. *A miner's pay-dirt, tailings, etc., are the products of his labor, and may be sold under execution against him.*

13. *School-warrants may be located on mineral lands. Nothing in the act of May 3d, 1852, prevents it.*

7 Cal. R. 110.

14. *To shut off water is as injurious as to turn it on in destructive quantities, and a dam may, on that account, be abated as a nuisance. Five years' adverse enjoyment of water rights fixes them.*

8 Cal. 77 and 136.

15. *A ditch owner must use that degree of care to prevent injury to others by the overflow of water, which prudent men use in similar circumstances.*

10 Cal. R. 541.

An engine or other machinery set up for mining purposes becomes a fixture, and passes to a landlord as a fixture annexed to the freehold.

Merrit v. Judd, July Term, Cal. Sup. Court, 1859.

III. Some Principles of Spanish Mining Law, and the Manner in which a Mine is "Denounced."

All the principal provisions of the mining code of Spain and those American States which have at some time been attached to the Spanish Crown, were promulgated in the latter part of the sixteenth century, or, to speak accurately, in 1761 and in 1783.

The publication made at the former date was a compilation of former and ancient laws on the mines, with extensive notes by GAMBOA, a learned civilian and a royal minister. In referring to this compilation, it will be called simply the *Law of Gamboa*. In 1783, an elaborate code or body of instructions was issued in the form and with the authority of a royal decree by King JOSEPH D. GALVEZ. This is referred to as the *Law of Galvez*.

When Mexico became independent of Spain, these mining codes were not abolished, but declared to be in force; and they continue now to be the law of those States on the subject of mining, except in a few points where they have been modified or abrogated by decrees of Presidents, and this principally as regards the rights of foreigners to hold and work mines. By the laws of Spain, these mines do not pass by a grant of the land, but remain in the crown, subject to be disposed of according to such ordinances and regulations as might be from time to time adopted. Any individual might enter upon the lands of another to search for the ores of the precious metals, and, having discovered a mine, he might register, and thus acquire the right to work it, on paying to the owner the damage done to the surface, and to the crown, whose property it was, a fifth or a tenth, according to the quality of the mine.

If the finder neglected to work or worked it imperfectly, it might be denounced by any other person, where-by he would become entitled.

This right to the mines of precious metals, which by the laws of Spain remained in the crown, was also retained by Mexico while she was sovereign of the terri-

tory, and in the case of Arizona and California and New-Mexico, is held to have passed to the United States.

It is to be observed that the regulation permitting the acquisition of a right in the mines by registry or by denouncement, was simply a mode of exercising, by the sovereign, the proprietary right which he had in the treasure as it lay in and was connected with the soil.

See Report of Hon. Thos. Ewing, Sec. of Int., Dec. 3, 1849.

OF THE DISCOVERY AND REGISTRY OF MINES.

From the Law of Galvez.

1. The discoverers of one or more mineral mountains where no mine or shaft has been opened before, acquire, in the principal vein, as much as three portions, where it best pleases them, and on discovering more veins, shall have a portion in each, fixing on and making these portions in ten days.

2. The discoverer of a new vein in a mountain known and worked in other parts may hold in it two portions, either conterminous or separated by other mines, on condition that he specifies in ten days, as above provided.

3. The discoverer shall present to the miners' court or deputation, or to the officer indicated by the church, a description of the mountain and its mine, and a copy of this notice may be posted on the doors of the churches and government houses. Within ninety days, the discoverer must make, or cause to be made, a pit, a yard and a half square and ten yards deep; and immediately after the existence of the vein is ascertained, one of the deputies or a clerk shall visit it in person, or two assisting witnesses in the absence of the clerk and deputy, and the Mining Professor of the territory, in order that the course, width, direction, inclination, hardness or softness, and the firmness of the bed may be noticed and recorded with the grant of possession to be given in the king's name to the discoverer.

The discoverer shall also inclose his vein by stakes, and a copy of the proceedings shall be given him for the security of his title.

4. Within ninety days, questions as to first discovery may be heard, and judgment given to him who best proves his claim.

5. Restorers of old mines which have been abandoned and left to decay shall enjoy the same privileges as discoverers, of possessing three parts in the principal vein and one in each of the others, and both revivers and discoverers shall have preference over all others under equal circumstances.

6. He who first finds metal in a vein, and in case of further doubt, he who registers first, shall be considered the discoverer.

7. The denouncer of a deserted mine shall set forth the circumstances set forth in Section 3, the existence of the mine, the name of the last possessor, if known, the owners of neighboring mines; and they shall be duly summoned. Not appearing within ten days, the denouncement shall be publicly declared on the three following Sundays. This meeting no opposition, the denouncer shall be informed that within sixty days he must have cleared away rubbish and erected considerable works, or cleared and sunk a shaft to some depth, at least ten vertical yards. The Professor of Mines shall visit, if possible, and examine the pits and works, and report and record their condition.

8. If the former owner does not appear till after the three public proclamations are made, and the denouncer has commenced his sixty days for refitting the mine, the question of right in the property only can be examined. If the former owner makes his claim good, he shall refund all the expenses incurred by the denouncer, who has acted in good faith.

9. The denouncer who does not complete his shaft in sixty days loses his right, and the mine may be denounced by another; but in case of serious or unforeseen obstacles, the Territorial Deputation has power to give him an extension of time.

10. One may discover and denounce a mine, not only on public lands, but on private property, provided he pays

for the extent of surface above the same and for the damage resulting to the owner from working the mine.

11. An ancient mining site may also be denounced on giving the former owner four months' notice to come and sell, or let the improvements. But if the roofs of the buildings are gone, no notice is required.

12. Two contiguous mines on the same vein can not be acquired by denouncement. One may be held by denouncement and the other by purchase, gift, inheritance, or other title.

OF MEASURES AND SPACES IN MINES.

From the Law of Galvez.

Every miner may claim in length on a vein of gold, silver, or other metal, two hundred yards.

When the vein is perpendicular to the horizon, a hundred level yards, either all on one side or fifty on each side of the vein, shall be measured off to the mine owner. This quantity is increased to two hundred yards and more, according as the vein inclines.

With regard to banks, placers, and beds of ore, the space to be claimed by the miner shall be regulated by the local mining court, or deputation of miners.

If a miner, following his vein beneath the surface, enters upon unclaimed soil, (virgin lands,) he is not obliged to desist, but must denounce his new property.

Where a vein takes its rise in one mine, and is found to run into another, the owner of the mine where it was first worked, and from which it passes, has no claim to it after it passes out from his claim.

OF SUPPORTS IN MINES AND OF THE ABANDONMENT OF MINES.

From the Law of Galvez, Chap. IX.

All persons are strictly prohibited from taking away, or in any degree weakening or diminishing, the pillars, beams, and necessary supports of mines, on pain of ten years' imprisonment.

But a mine owner may remove the pillars of ore which

support his mine, if he replace them by others of mason-work, under the inspection of the Mining Professor.

Whoever fails to work his mine for four successive months with at least four paid workmen operating either within or on ores without the mine, shall be held to have abandoned it, and it becomes then liable to denouncement by another.

He must work his mine eight months each year, unless prevented by war or pestilence.

Any one intending to abandon his mine must give notice of the same, and it must be examined and described, and a chart made of it, and the whole deposited in the archives for the inspection of all persons who may wish to see it or take a copy of it.

OF MINES WORKED BY COMPANIES.

From the Law of Galvez, Chap. XI.

Companies have the right of denouncing four new portions or four deserted mines, even though they should be contiguous and on the same vein.

The custom of dividing a mine into twenty-four equal shares shall continue to be observed.

A person failing for four months to contribute his share of the expenses of working the mine, shall forfeit his interest in favor of the partners who contribute.

If a partner refuses to contribute to the "dead works" of a mine, the rest of the partners may retain and devote to this purpose his share of the products of the mine.

In the dissolution of a partnership by mutual consent, each partner, on going out, may sell his interest to a third person, but he ought to give his former partner the first offer.

The sale of an interest in a mine can not be rescinded on account of the fact that after such sale the mine becomes of very great value.

THE DIFFERENCE BETWEEN REGISTRY AND DENOUNCEMENT.

From the Law of Gamboa, Chap. V. Sec. 21.

There is substantially no difference between denouncement and registry, although there is a difference in form. Registry generally applies to newly-discovered mines, and denouncement to mines which have been discovered before, but which having been forfeited under the ordinances, as a penalty for being kept insufficiently worked for four months, or for not sinking the shaft after registry or denouncement, as provided by the ordinances. In making registry, the person, the place, and the ore only are required to be set forth. But the denouncement of a mine for not being sufficiently worked is in the nature of a summary judgment on the case, and all the facts and reasons require to be set forth.

The order in denouncement proceedings is as follows:

1st. A bill is filed, setting forth the insufficient working or the abandonment of a mine.

2d. The depositions are taken, and the former owner notified.

3d. The parties are to be heard, if they appear. If the former worker of the mine does not appear in sixty days,

4th. The judge then proceeds to give possession to the applicant, subject to the obligations of sinking the pit and keeping the account required by law.

RIGHTS OF FOREIGN RESIDENTS IN MEXICO.

The decree of *Comonfort*, of February first, 1856, provides:

That foreigners settled in, and residents of the Republic, may acquire and possess real estate either in town or country, including mines of all classes of minerals, coal included, either by purchase, adjudication, denouncement, or any other title known to the common laws or mining ordinances.

But a foreigner shall not acquire real estate within

twenty leagues from the line of the frontier of Mexico, without gaining special permission.

The decree of *Juarez*, of sixteenth March, 1861, provides:

That foreigners shall be registered at the office of the Secretary of State, and foreign relations within three months from date of decree.

That courts of justice, whenever a suit is brought before them by a foreigner, shall require his certificate. And:

That no notary public shall acknowledge any instrument executed by a foreigner without previously having seen the certificate, of which fact he shall make mention in his *proces-verbal*.

The fee for issuing said certificate shall be two dollars.

IV.—General Mining Laws of Arizona.

Being an abstract of the law on mining, passed by the Territorial Legislature, to take effect on the first January, 1865.

TITLE I.—REGISTRY AND CONVEYANCE OF MINES.

Sec. 1 provides: That all mining rights on the public lands of the United States are, in their nature possessory only.

Sec. 2. That the Judges of the Probate Courts in their respective counties shall have jurisdiction of the registry and denouncement of all mines. He has the right of summary judgment in all mining questions, and his records are to be entitled: "Probate Court—Judicature of Mines."

Sec. 3. That clerks of Probate Court are *ex officio* recorders of mines and mineral and auxiliary lands in their respective counties.

Sec. 4. That county commissioners shall provide a building for these officers, where all land and mine records are kept, as also a cabinet of different specimens of ores.

Sec. 5. That three books are to be kept, marked A, B, C, respectively, always open to inspection.

Sec. 6, 7, 8. Book "A" to contain registry, claims, etc., of all mines previous to the effect of this act, (January first, 1865.) All preliminary registries and denouncements in book "B," and all second registries, after the sinking of the shaft, etc., in book "C." The recorder shall keep a seal of office, and affix it to all his official documents.

Sec. 9. That he shall receive for record of claim in book "A," \$1; for preliminary registry in "B," \$1; for final record and certificate in "C," \$2; articles of partnership, \$250.

Sec. 10. Charters of mining companies, the location of their mines, office, etc., recorded in book "C."

Sec. 11. That all agreements of partners are to be recorded, or held as in contempt, and fined not over \$100, at discretion of Probate Judge.

Sec. 12. That all claims are to be registered in the name of the true owner; all entries in fictitious names forfeited, and the mine liable to denouncement.

Sec. 13. Mines and mineral lands to be regarded as real estate.

Sec. 14. All sales of mining property to be recorded in three months, or open to denouncement, the transfers to be as real estate, and subject to same rules.

TITLE II.—EXTENT OF MINING RIGHTS, AND MODE OF ACQUIRING AND RETAINING TITLES.

Sec. 15 provides: That every mining claim, or pertinencia, shall consist of a superficial area of two hundred yards square, measured so as to include the principal vein, and following its dip. But mining districts may make laws of their own, only so as not to give more than the two hundred yards prescribed in one claim, and not to diminish the territorial claim of one pertinencia, as provided.

Sec. 16. That any person discovering or denouncing a new or a long-abandoned mine, shall be entitled to two claims.

Sec. 17. Companies entitled to one discovery-claim only on each lode.

Sec. 18. Mill site of not more than a quarter-section may be preempted. Right to build a dam. Must spend one hundred dollars or more within three years, or forfeit the site. By doing a certain amount of work, say thirty days each year, gives right of confirming the title.

Sec. 19. Mining claims to be staked off, public notice of the claim posted up, and the claim registered within three months.

Sec. 20. Sanction of Judge of Probate required to change boundaries once fixed.

Sec. 21. All minerals, wood, water, and grass on a mining claim belong exclusively to owner; yet can not prevent transient persons from using waters, nor Legislature from making equitable disposition of the water for advantage of others.

Sec. 22. Public roads not to be fenced, choked with rubbish, or changed without sanction of authorities.

Sec. 23. Of veins prospected at same time, the first who proves occupancy has right of location. Claims may be shifted, so as to take up a small intermediate space. Parties to locate on a mineral vein or deposit in the order of their arrival.

Sec. 24. When two or more parties locate or prospect on the same vein, and the one first on the ground fails either verbally or by writing to give notice of priority, the intervening space may be divided between them, if not exceeding the allowable quantity.

Sec. 25. Previous mining laws and acts declared valid. All rights, claims, and titles declared valid. No right considered as abandoned if claimant files with the clerk of the Probate Court a brief description of the same. All records and papers before deposited with District Recorders valid, if deposited with clerk of the Probate Court within three months; nor invalid for want of form, if they are so as to be understood. Conveyances of mines, minerals, lands, etc., valid, if in a shape to be understood, and deposited with clerk of Probate Court within three months.

Sec. 26. Every recorder, register, or clerk shall, within three months from passage hereof, deposit with clerk of Probate Court all his books and documents, under penalty of fine and imprisonment.

Sec. 27. Recorders of mining districts continued in office on taking oath before clerk of Probate Court. He shall keep in a book all notices of claims to veins, etc., and time of receiving all papers. He shall go with claimant to inspect his claim, and his metes and bounds, and mark them with substantial monuments before a witness, whose name shall be entered on the record. He is to visit shafts, and note their depth, and shall, every quarter, file copies of all his papers with the Probate clerk of the county.

Twelve persons owning contiguous mining claims may make a new mining district if their claims are outside any established district, elect recorder, etc., who shall be governed by above rules.

Sec. 28. All claimants to sink a shaft of thirty, or run a tunnel of fifty, feet within a year. Recorder to inspect it. Specimens of the ores to be kept and given to the University of Arizona.

Sec. 29. Within thirty days after record made by clerk of court, as above, upon showing all provisions of law complied with, and all adverse claimants warned in the territorial paper to appear and show claim, the Judge of Probate may issue a decree, giving perfect title till January first, 1868, and ever after, unless property is abandoned. Clerk shall give copy of decree, which shall be regarded a perfect title for claimant.

All claimants in possession of claims may sue out this decree by complying with the above requisitions, and causing their shafts to be examined by proper officers.

Sec. 30. By reason of Indian wars and the disordered state of the Territory, the time fixed for sinking shafts, etc., shall not begin to run for two years, namely, till first January, 1867; but parties who sink shafts, and comply with the law, can have their titles confirmed.

Sec. 31. Neither single claimant nor company compelled to sink shaft, or other improvement, on more than

one tract claimed, but may concentrate capital and labor on any point their interest may require.

Sec. 32. After work required by Sec. 28, two years is allowed for getting machinery, etc., on the property. But each year before the first of June he shall file with Probate Judge a statement that he does not abandon the mine. After two years he must work his claim thirty days at least a year, unless prevented by hostile Indians, or other good cause, to be stated to Probate Judge.

Sec. 33. Persons discovering a vein in any part of a county where there is no recorder, may make record with the county clerk of Probate Court.

Sec. 34. Discoverers of mines on lands in legal ownership or possession of others, shall pay, or give bond to pay, owner all damages caused by working the mine. Tunnels also may be run through public or private property upon paying damages, or agreeing to pay damages. But the claim must not be set up after the tunnel is projected or commenced.

Sec. 35. If such tunnel shall intersect mineral deposits or lodes held by others, the owners can pay one half the expense of the tunnel, and have all the ore taken from the claim, or can divide the ore, the tunnel company bearing all the expenses of the same.

Sec. 36. If in running such tunnel, new veins are struck, they may be registered by the party making the tunnel.

TITLE III.—ABANDONMENT AND RE-LOCATION OF MINING RIGHTS.

Sec. 37. Claimants not complying with the foregoing conditions and obligations, shall forfeit their claims, and may not register anew for three years. The claims open to all but the party forfeiting them by neglect.

Sec. 38. Veins and deposits not worked since the acquisition of Arizona by the United States, considered as abandoned, and subject to denouncement.

Sec. 39. Works hereafter abandoned to be governed by the provisions of this act.

Sec. 40. In case a mine is abandoned, and machines or works left on it, the party denouncing is to give three months warning in nearest newspaper, and by posting in three places. Three months after the expiration of the warning, these works go to the denouncer, and the former owner gets nothing for them.

Sec. 41. Persons on mineral lands before abandonment, by this law ousted by order of the Probate Judge.

TITLE IV.—PROCEEDINGS IN LITIGATED MINING CASES.

Sec. 42. All litigation about mines in the nature of equity proceedings; judge to hear and determine all cases on equitable principles.

Sec. 43. Evidence in writing and testimony of witness out of Territory taken by commission.

Sec. 44. Appeal lies from Probate to District Court, if taken in ten days, party cast giving bond to cover costs and damages.

Sec. 45. Cases on appeal to be tried on the record; but on affidavit of great importance and recent discovery, new proof may be admitted before the District Court.

Sec. 46. Writ of error and appeal taken to Supreme Court.

Sec. 47. District Courts have power to issue writs of mandamus, certiorari, prohibition, etc., to Probate Courts.

Sec. 48. Probate Judge, in litigated mining cases, can commission three experts to investigate a mining question, paid five dollars per day.

Sec. 49. All questions of lines and boundaries shall be decided summarily by the Probate Judge, who may, at any time, call in the aid of a commissioner.

Sec. 50. Partners disagreeing as to working a mine, may effect a partition before the Probate Judge. Also, when a partner does not contribute to the working of a mine, the judge may appoint an agent for him, so the work may go on; but he can not be charged with expenses thus incurred without his knowledge.

TITLE V.—OF THE TERRITORIAL CLAIM, AND OF ALLUVIAL AND DILUVIAL DEPOSITS.

Sec. 51. It shall be the duty of persons who may discover and claim mining rights, or mineral lands, as they bound their claim or lode, at the same time to lay off and define the boundaries of one pertinencia, as required by the provisions of this act, adjoining their claim or claims, which shall be the property of the Territory of Arizona. Claimants failing to do this, forfeit all right to their claim or lode. Recording officers are to make such record under penalty, and forward a copy to the treasurer of the territory. In six months treasurer may sell such claim at auction, proceeds to go to fund for fighting the Indians, and afterward into a sinking-fund for school purposes.

Sec. 52. The extraction of gold from placer mines, namely, alluvial or diluvial deposits, shall not be considered mining proper, and shall not entitle the miner in such deposits to the provisions of this chapter, no section of which shall be so construed as to refer to extraction of gold from placer or bar mines.

Sec. 53. This chapter shall be in force and take effect from and after January 1st, 1865.

V.—Peculiarities of General and Local Law in different States, as Nevada, Colorado, Idaho, Montana, and New-Mexico.

NEVADA.

Mine owners whose works or property may be in any way injured or seriously threatened by adjoining mining operations, can sue, have the question settled by experts, and get judgment that shall operate a mortgage on the mine against which the judgment is obtained.

Laws of Nev. 1862, p. 33.

No action for mining claim can be maintained, unless it appear that plaintiff or his assigns was in possession within two years before the commencement of the suit.

Laws Nev. 1861, p. 27.

When workmen, under written contract, sink a shaft,

or dig a tunnel, they have the mechanics' lien on the structure or excavation for their wages.

Laws Nev. 1861, p. 38.

All mining claims in Nevada must be conveyed by written instruments after the analogy of real estate. But former transactions may be judged by the provisions of the custom of local law.

Laws Nev. 1862, p. 12.

In actions respecting mining claims, proof shall be admitted of the customs, usages, or rules in force in each mining district.

Laws Nev. 1861, p. 410.

LOCAL MINING LAWS OF NEVADA.

These vary with almost every district, and the laws of the different districts vary each year on the acts by which possession is to be retained.

There are, however, certain general principles recognized in most of the mining codes; of which the following are the most important:

A discoverer of a new district, or class of diggings, can hold twice as much as ordinary miners.

Neglect to work a claim which is workable, works an abandonment and forfeiture.

Stakes or monuments of some description must be driven at each corner of a claim, and the names of owners posted on the claim.

In placer diggings, where the claims can only be worked a part of a year, claims are not forfeited for want of work during the season unfavorable for work.

Neglect to work for sickness does not generally invalidate a claim.

The diggers of shafts or tunnels on ground where the expense is great and the result uncertain, generally have two claims each. Companies may hold as much as the individual members could hold.

Work on any part of a claim secures the whole claim.

One claim is held by location, and generally any number by purchase.

The laws of Genoa District, as framed in 1861, pro-

vided that, by doing one thousand dollars worth of work on a claim, it was established to the claimant, without forfeiture, forever.

The laws of Paradise District, in Nye County, in 1865, provide that, by the simple record of the claims, they can be held one year, till April, 1866, when new laws are expected to be made.

The laws of Virginia District, for 1859, differ in some important respects from those enacted at a later day.

The last laws of Reese River District are declared to go into effect from and after the fourth June, 1864.

COLORADO.

The claims of soldiers in United States service exempted from levy and sale, and held as real estate for nine months after their period of enlistment.

Stat. of 1861, pp. 134 and 167.

The term "claim" is to mean one hundred feet on the length of the lode, unless differently provided in the district mining laws.

Stat. of 1861, p. 166.

Ditch companies can have the right of way, provided the water does not interfere with prior rights.

Stat. of 1861, p. 166.

Nor can a person dig or mine under the building of another without securing the parties against damage, except he have priority of right.

In case of lodes crossing, priority of claim shall determine rights; but a person shall not, under claim of priority, vary from the general direction of his lode when it crosses another.

Where two crevices are discovered at a distance from each other, and known by different names, but found to be on the same lode, priority of discovery shall determine right.

The question as to identity is settled by sinking shafts not less than fifty feet apart.

No person is to flood the claim of another, or wash tailings on it.

Right of way over a claim is guaranteed.

Stat. 1861, p. 167.

The records and rules of each district are to be filed with the county clerk, and admitted as evidence in mining questions.

Stat. 1861, p. 168.

Mining property is held under the district laws of the miners, not under the preëmption or homestead law, under which agricultural lands are held.

Stat. of 1861, p. 170.

Persons claiming a lot or claim under the rules of local miners' court, can have a writ of trespass against an adverse claimant.

Stat. 1861, p. 250.

One claim of one hundred feet in length is reserved on each lode for the benefit of schools.

Stat. 1862, p. 95.

All decisions, judgments, etc., of miners' courts or clubs confirmed and legalized.

Stat. 1862, p. 98.

AS TO TUNNELS.

Tunnel claims to be recorded with specifications.

In working tunnel claims, discovery of lode entitles to two hundred and fifty feet each way on said lode, but not to interfere with vested rights.

Stat. 1861, p. 166.

Tunnel companies must make full specifications as to names, claim, location, direction, etc. Such certificate to be forwarded to Secretary of Territory, recorded, and the company considered a body corporate within the law.

Such tunnel companies to hold 250 feet on each side of said tunnel, on lodes discovered by them; one hundred on lodes discovered by others, and crossing said tunnel. They have the right of way on all lodes crossed by them.

Stat. 1862, p. 50.

GENERAL MINING LAWS OF COLORADO, ADOPTED IN
MINERS' CONVENTION OF MARCH, 1860.

The first record of a claim holds it. Where a claim is in two districts, a record in either will hold it; but where a claim is wholly in one district, it must be recorded in that district.

All suits for claims are to be brought in the district where the claim is located, or a part thereof.

GENERAL PROVISIONS OF THE MINERS' CODE OF
GREGORY DISTRICT.

A claim on a lode is one hundred feet on the lode by fifty wide; in a gulch, one hundred from bank to bank; in patch diggings, one hundred square. A tunnel claim is for the entire distance intended and marked by a stake at the mouth. A mill site is two hundred and fifty feet square. A ditch, as shown by survey and stakes. Water claim is not to exceed two hundred and fifty feet. A ranch claim is one hundred and sixty acres. A building lot forty by one hundred.

No person to have more than one claim, except by purchase or discovery.

Discovery claims held by marking as such; purchase claims by record.

Claims not held by purchase or discovery, and abandoned for ten consecutive days, forfeited.

No claim good, unless staked off and well marked by name of owner or company.

A company working one claim of theirs, shall be held to work the rest by putting up a notice of the same.

Priority is always to be respected. Contracts of partnership, and most other contracts, to be in writing.

Deeds, bonds, etc., to be witnessed by two witnesses.

A gulch and a lode claim may be held at the same time, by working one of them.

Mill owner has right to cut sluice for his water.

Old claims held by former laws, are confirmed.

As to water claims, each has half, unless the supply is not enough for both; in that case priority determines.

So of several claims to use same water.

Right of way is given to water companies.

Other questions as to water, etc., governed by common law.

All claims but discovery claims must be recorded, unless continually worked.

Common law rules, as to digging under lots, etc., to be observed.

Tunnels to be located by description, and a four-square stake at mouth. On veins discovered in a tunnel, the proprietors of tunnel entitled to two hundred and fifty feet. They shall have right of way through other lodes.

IDAHO.

On the twenty-eighth December, 1864, the Legislature of this Territory passed an act concerning corporations for mining. It does not differ in any material respect from similar corporation acts passed by the legislatures of other States and Territories. The rules with respect to patch and gulch claims, discovery, occupation, and abandonment are very nearly the same, as in Nevada and Colorado.

MONTANA.

The mining law of this new mining territory, passed December twenty-sixth, 1864, is, in substance, as follows:

Sec. 1. Discoverers to have one claim by right of discovery, and one by preëmption.

Sec. 2. A crevice of quartz ore with ore wall necessary, in order to record claim.

Sec. 3. Claims to be for not more than two hundred feet, with dip, spurs, and angles. But in case of two lodes near each other, the ground shall belong equally to the claimants of said lodes.

Sec. 4. When lodes cross, the ore in the crossing belongs to lode first discovered.

Sec. 5. Before record, good stakes with proper inscriptions must be set up on the lode, and renewed, if necessary, every year.

Sec. 6. Notice of discovery or preëmption on any lode to be filed within fifteen days, and the claimant must swear that he is truly a resident of Montana. Specimen must also be deposited in recorder's office.

Sec. 7. Persons destroying stakes and other marks to be punished by fine and imprisonment.

Sec. 8. Amount that may be taken up on a lode limited to one thousand feet.

Sec. 9. Lead and quartz claims as real estate, and descend to heirs, etc., as such.

Sec. 10. Claims recorded previous to this act held as those recorded since.

Sec. 11. Previous and inconsistent acts repealed.

Subsequently an important act passed the Montana Legislature, allowing married men to convey mining and real estate claims without wife's signature.

The district mining laws of Montana are much like those of Colorado. The amount of work to be done on different claims varies greatly from districts where the work must be continuous and daily, to those where one day in a month, or two months, or less in a year will hold the claims.

SOME ACCOUNT OF THE MINING REGULATIONS OF BRITISH COLUMBIA.

1. By the rules of January sixth, 1860, the mines are to be divided into "bench-diggings" and "dry-diggings."

2. On bench-diggings ordinary claims shall be registered, either one hundred feet square, or a strip of land twenty-five feet deep, at the edge of the cliff next the river, bounded by two straight lines running as nearly as may be at right angles to the creek to the foot of the descent in the rear.

3. Gold commissioner has authority to increase it to what he considers an adequate claim where the ground is very irregular.

4. He may allow the free miner to register two claims where the pay-dirt is thin; but no person holds more than two. A discoverer's claim is double.

5. All claims subject to right of way and water, not worked within ten feet of road.

6. In measuring water, the area of a vertical transverse section of trough shall be taken. This trough to be square, and its top not over seven, nor the bottom over seventeen inches from top of water in dam, or reservoir. Same measurement applied to a ditch.

AS TO PURCHASE OF LANDS BY ALIENS.

By law of England, which is also law of British Columbia, an alien may hold lands, but is liable to have them forfeited.

No other than crown officers can disturb an alien in his possession.

3. The colonial government secures to aliens the full right of possession and enjoyment for three years. At the expiration of this time they must either naturalize as British subjects, or convey to subjects.

Foreigners are not entitled to grants of waste land of the crown. Naturalization granted to all who desire it.

Congressional Mining Bill.

Be it enacted by the Senate and House of Representatives of the United States of America, in Congress assembled,

SECTION 1. That the mineral lands of the public domain, both surveyed and unsurveyed, are hereby declared to be free and open to exploration and occupation by all citizens of the United States, and those who have declared their intentions to become citizens, subject to such regulations as may be prescribed by law, and subject also to the local customs or rules of miners in the several mining districts, so far as the same may not be in conflict with the laws of the United States.

SEC. 2. And be it further enacted, That whenever any person or association of persons claim a vein or lode of quartz, or other rock in place, bearing gold, silver, cinn-

bar, or copper, having previously occupied and improved the same according to the local custom or rules of miners in the district where the same is situated, and having expended in actual labor and improvements thereon an amount of not less than \$1000, and in regard to whose possession there is no controversy or opposing claim, it shall and may be lawful for said claimant or association of claimants to file in the local land office a diagram of the same so extended laterally or otherwise as to conform to the local laws, customs, and rules of miners, and to enter such tract and receive a patent therefor, granting such mine, together with the right to follow such vein or lode with its dips, angles, and variations, to any depth, although it may enter the land adjoining, which land adjoining shall be sold subject to this condition.

SEC. 3. And be it further enacted, That upon the filing of the diagram as provided in the second section of this act, and posting the same in a conspicuous place on the claim, together with a notice of intention to apply for a patent, the register of the land office shall publish a notice of the same in a newspaper published nearest to the location of said claim, and shall also post such notice in his office for the period of ninety days; and after the expiration of such period, if no adverse claim shall have been filed, it shall be the duty of the surveyor-general, upon application of the party, to survey the premises and make a plat thereof, indorsed with his approval, designating the number and description of the location, the value of the labor and improvements, and the character of the vein exposed; and upon the payment to the proper officer of \$5 per acre, together with the cost of such survey, plat, and notice, and giving satisfactory evidence that said diagram and notice have been posted on the claim during said period of ninety days, the register of the land office shall transmit to the General Land Office said plat, survey, and description, and a patent shall issue for the same thereupon. But said plat, survey, or description shall in no case cover more than one vein or lode, and no patent shall issue for more than one

vein or lode, which shall be expressed in the patent issued.

SEC. 4. And be it further enacted, That when such location and entry of a mine shall be upon unsurveyed lands, it shall and may be lawful, after the extension thereto of the public surveys, to adjust the surveys to the limits of the premises, according to the location and possession and plat aforesaid, and the surveyor-general may, in extending the surveys, vary the same from a rectangular form to suit the circumstances of the country and the local rules, laws, and customs of miners: Provided, that no location hereafter made shall exceed two hundred feet in length along the vein for each locator, with an additional claim for discovery to the discoverer of the lode, with a right to follow such vein to any depth, with all its dips, variations, and angles, together with a reasonable quantity of surface for the convenient working of the same as fixed by local rules: And provided further, That no person may make more than one location on the same lode, and not more than three thousand feet shall be taken in any one claim by any association of persons.

SEC. 5. And be it further enacted, That as a further condition of sale, in the absence of necessary legislation by Congress, the local legislature of any State or Territory may provide rules for working mines, involving easements, drainage, and other necessary means to their complete development; and those conditions shall be fully expressed in the patent.

SEC. 6. And be it further enacted, That whenever any adverse claimants to any mine, located and claimed as aforesaid, shall appear before the approval of the survey as provided in the third section of this act, all proceedings shall be staid until a final settlement and adjudication in the courts of competent jurisdiction of the rights of possession to such claim, when a patent may issue as in other cases.

SEC. 7. And be it further enacted, That the President of the United States be, and is hereby, authorized to establish additional land districts and to appoint the

necessary officers under existing laws, whenever he may deem the same necessary for the public convenience in executing the provisions of this act.

SEC. 8. And be it further enacted, That the right of way for the construction of highways over public lands, not reserved for public uses, is hereby granted.

SEC. 9. And be it further enacted, That whenever, by priority of possession, rights to the use of water for mining, agricultural, manufacturing, or other purposes, have vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and decisions of courts, the possessors and owners of such vested rights shall be maintained and protected in the same; and the right of way for the construction of ditches and canals for the purposes aforesaid, is hereby acknowledged and confirmed: Provided, however, That whenever, after the passage of this act, any person or persons shall, in the construction of any ditch or canal, injure or damage the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage.

SEC. 10. And be it further enacted, That wherever, prior to the passage of this act, upon the lands heretofore designated as mineral lands which have been excluded from survey and sale, there have been homesteads made by citizens of the United States, or persons who have declared their intention to become citizens, which homesteads have been made, improved, and used for agricultural purposes, and upon which there have been no valuable mines of gold, silver, cinnabar, or copper discovered, and which are properly agricultural lands, the said settlers or owners of such homesteads shall have a right of preëmption thereto, and shall be entitled to purchase the same at the price of one dollar and twenty-five cents per acre, and in quantity not to exceed one hundred and sixty acres; or said parties may avail themselves of the provisions of the act of Congress, approved May 20, 1862, entitled, "An act to secure

homesteads to actual settlers on the public domain," and acts amendatory thereof.

SEC. 11. And be it further enacted, That upon the survey of the lands aforesaid, the Secretary of the Interior may designate and set apart such portions of the said lands as are clearly agricultural lands, which lands shall thereafter be subject to preëmption and sale as other public lands of the United States, and subject to all the laws and regulations applicable to the same.

ASSAYS OF ORES.

Samples of ores from mines in Pah-Ranayat district, belonging to the Pah-Ranayat Central Silver Mining Company, which were assayed in this city, yielded as follows :

1. Hampden, at the rate per ton (2000 lbs.) of	\$336 92 silver.
2. Saturn, " " " "	301 45 "
3. Mars, " " " "	65 61 "
4. Williams, " " " "	878 09 "
5. Moscow, " " " "	150 73 "
6. Comanche, " " " "	372 40 "
7. Quebec, 53 per cent lead, containing per ton	42 66 "
8. Lexington, at the rate per ton of	1751 15 "
9. Vesuvius, " " " "	196 07 "
10. Leonidas, " " " "	106 40 "
11. London, " " " "	34 77 "
12. Braganza, " " " "	1950 65 "
13. Pittsburg, " " " "	159 60 "
14. Cliff, " " " "	266 00 "
15. Hamburg, " " " "	101 09 "
16. Judson, " " " "	143 64 "
17. Steuben, " " " "	124 13 "
18. Inca, " " " "	367 08 "
19. Mazeppa, " " " "	381 25 "
20. Gibraltar, " " " "	620 35 "
21. Exenica, " " " "	691 60 "
22. Manchester, " " " "	514 25 "

Samples from the International Silver Company's mines in the same district assayed as follows :

1. Gibraltar, at the rate per ton of 2,000 lbs.	\$620 65 silver.
2. Comanche, " " " "	272 40 "
3. Xenia, " " " "	691 60 "
4. Vesuvius, " " " "	195 07 "
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11. Inca, " " " "	367 08 "
12. Quebec, 50 per cent of lead containing per ton.	42 66 "

INDEX.

	PAGE
Frontispiece: Hydraulic Process, Fig. 30,.....	v.
Preface to First and Second Editions,.....	vii.
Preface to Third Edition,.....	
On the Nature of the Deposits of Metals and their Ores, and the General Principles of Mining,.....	5
I. Superficial Deposits,.....	6
II. Stratified Mineral Deposits,.....	7
III. Unstratified Deposits,.....	8
Irregular Deposits,.....	9
Stockwerks,.....	11
Fahlbands,.....	14
Regular Deposits,.....	16
Veins of Sedimentary Origin,.....	17
Veins of Attrition,.....	17
Veins of Infiltration, or Stalactitic Veins,.....	17
Plutonic Veins,.....	18
Segregated Veins,.....	18
Gash Veins,.....	20
True Veins,.....	22
Theories of the Formation of Mineral Veins,.....	33
The General Principles on which the Contents of a Vein of moder- ate width are removed,.....	42
Exploitation of Thick Veins and Masses,.....	52
Timbering of Mines,.....	52
Manual of Mining and Metallurgy,.....	59
Classification of Rocks,.....	61
Of the Instruments and Processes of Subterranean Opera- tions,.....	61
Means of penetrating into the Interior of the Earth,.....	61
Metals: Their Chemistry and Geology,.....	63
Gold,.....	63
Platinum,.....	64
Silver,.....	65
Mercury,.....	68
Copper,.....	69
Iron,.....	71
Lead,.....	74
Tin,.....	74

	PAGE
Zinc,	75
Manganese,	76
Cobalt,	77
Nickel,	78
Bismuth,	78
Arsenic,	78
Antimony,	79
Anthracite, Bituminous Coal, Lignite, Rock Salt, Limestone, Gypsum, Clay, Plumbago, Precious Stones,	80
Standard of Gold,	81
Table showing Quantity of Gold in a Ton of Ore,	82
Specific Gravity,	82
To find the Amount of Gold in a Gold Quartz,	86
The Mines of California, Oregon, Nevada, British Columbia, etc., with Statistics of Production,	87
Placer Mining, etc., Figs. 18 to 25,	95
Processes for the Reduction of Gold,	105
Hydraulic Mining, Figs. 27 to 30,	107
Metallurgy of Gold,	111
Amalgamation in the Battery,	112
Amalgamation in the Arastra,	113
Amalgamation in Iron Pans,	114
Chlorination Process,	114
Metallurgy of Silver,	117
Wet Process, Figs. 31 to 38,	117
Roasting Process,	126
Barrel Amalgamation, Figs. 39 and 40,	130
Amalgamation in Dr. Veatch's Steam Tubs,	137
Amalgamation in Pans,	139
Amalgamation in Heaps, (Patio,) Figs. 41, 42,	139
Melting Process,	144
Processes of Augustin, Ziervogel, and Von Patera,	144
Descriptions of Furnaces, Machines, etc.,	149
Furnace for Roasting Silver Ores, Figs. 43 and 44,	149
Roasting Furnace, with Rotating Hearth, Fig. 45,	150
Crucible Furnace, Fig. 46,	151
Furnace for "Retorting," Figs. 47 and 48,	151
Furnace for Smelting Silver Ores, Figs. 49, 50, 51,	152
Cupellation Furnace, Figs. 52, 53,	154
Wet Crushing, Fig. 26,	155
Beath's Amalgamator, Fig. 54,	155
Boston Milling and Manufacturing Co.'s Machines, Figs. 55 to 59, ..	157
Crosby & Thompson's Process, Figs. 60, 62,	168
Whelpley & Storer's Process,	171
Gardiner's Machine, Figs. 63, 64, 65, 66,	173
Rix & Logan's Hammer Quartz Mill, Fig. 67,	179
Kent's Process, Fig. 68,	179
Hogan's Process, Figs. 69, 70, 71,	181
Bruckner's Furnace, Fig. 72,	185

	PAGE
Wheeler & Randall's Grinders and Amalgamators, Figs. 73, 74,...	185
Wilson's Desulphurizer,.....	185
Lyons Process,.....	187
Behr and Keith's Process,.....	189
Mason's Process,.....	190
Monnier's Process,.....	191
Bullock's Processes, Figs. 75 to 79,.....	201
Crookes's Method of Amalgamating with the Aid of Sodium,....	212
Blake's Rockbreaker, Fig. 80,.....	215
Hughes's Atmospheric Ore-Stamp, Fig. 81,.....	217
Patterson's Guyaskutus, Fig. 82,.....	219
Furnace for Extraction of Quicksilver, Fig. 83,.....	219
Barron's Concentrator, Fig. 84,.....	221
Elevating Machine for Mines, Fig. 85,.....	221
Reynolds's Turbine, Figs. 86, 87,.....	224
Washoe Tool Manufacturing Company's Picks, Fig. 88,.....	227
Pan for Dry-Washing, Fig. 89,.....	227
Leschot's Annular Diamond Drill, Fig. 90,.....	227
Gaston's Amalgamator,.....	232
Assaying—Principles of the Blow-Pipe, Figs. 91 to 100,.....	235
Systematic Proceeding for Determination of Gold and Silver Ores,	248
Description of Gold Ores,.....	250
Description of Silver Ores,.....	252
Abstract of Mining Laws and Regulations of Pacific States, Mexi- co, Colorado, and the British Possessions,.....	259
I. General Principles of Mining Law,.....	259
II. Principles of Mining Law established by the California Courts,.....	262
III. Principles of Spanish Mining Law, and Manner of "De- nouncing" a Mine,.....	267
IV. General Mining Laws of Arizona,.....	273
V. Peculiarities of General and Local Laws in different States and Territories, as Nevada, Colorado, Idaho, Montana, and New-Mexico,.....	279
Congressional Mining Bill,.....	286
Assays of Ores,.....	291

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